IUCN – The World Conservation Union

Founded in 1948, The World Conservation Union brings together States, government agencies and a diverse range of non-governmental organizations in a unique world partnership: over 1000 members in all, spread across some 140 countries.

As a Union, IUCN seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable.

The World Conservation Union builds on the stengths of its members, networks and partners to enhance their capacity and to support global alliances to safeguard natural resources at local, regional and global levels.

IUCN Wetlands & Water Resources Programme
Rue Mauverney 28
CH-1196 Gland, Switzerland
Tel:+41 22 999 0000
Fax:+41 22 999 0002
E-mail: wwrp@iucn.org
www.iucn.org/themes/wetlands/

IUCN Publications Services Unit
219c Huntingdon Road
Cambridge, CB3 0DL,
United Kingdom
Tel:++44 (1223) 277-894
Fax:++44 (1223) 277-175
E-mail: info@books.iucn.org
www.iucn.org/bookstore/

IUCN
The World Conservation Union

The rehabilitation of the delta of the Senegal River in Mauritania

IUCN

IUCN
Wetlands
and Water
Resources
Programme

BLUE SERIES

The rehabilitation of the delta of the Senegal River in Mauritania

Fielding the ecosystem approach

Olivier Hamerlynck & Stéphanie Duvail
IUCN Mauritania

IUCN
The World Conservation Union

The rehabilitation of the delta of the Senegal River in Mauritania

Fielding the ecosystem approach

Olivier Hamerlynck & Stéphanie Duvail

The Diawling National Park Restoration Programme initiated in 1989 is a joint venture between the Ministry of Environment of Mauritania and UICN - The World Conservation Union, mainly with support from the Netherlands Ministry for Development Cooperation (DGIS) and the French Global Environment Facility (FFEM).

This publication has been made possible in part by funding from the Government of the Netherlands

Published by: IUCN, Gland, Switzerland and Cambridge, UK

IUCN
The World Conservation Union

Citation: Hamerlynck, O. and Duvail, S. (2003). The rehabilitation of the Delta of the Senegal River in Mauritania. IUCN, Gland, Switzerland and Cambridge, UK. viii + 88 pp.

ISBN: 2-8317-0751-X

Design by: PSU and Elroy Bos

Editing: Starr Pirot

Cover photograph: "At long last, the water is back": a tense moment for Diawling National Park staff as they observe the first trial dry season managed flood release through Lemer sluice-gate - 9 April, 1997. See also Box 3, page 29.

Printed by: Sadag Imprimerie - 01200 Bellegarde, France

Available from: IUCN Publications Services Unit
219c Huntingdon Road, Cambridge CB3 0DL, United Kingdom
Tel.: +44 1223 277894, Fax:+44 1223 277175
E-mail: info@books.iucn.org
http://www.iucn.org/bookstore

A catalogue of IUCN publications is also available

The text of this book is printed on couché mat 115g, chlorine-free paper.

Dedicated to the memory of Adrian Adams who, until that tragic day in September 2000, was the eloquent voice of the farmers and fisherfolk of the central Senegal River valley. Readers are encouraged to savour her moral testament entitled *"Social impacts of an African dam: equity and distributional issues in the Senegal River Valley"*, which covers much more than the title suggests (download from *www.dams.org*). Perpetuating and optimising managed flood releases from Manantali and Diama dams to annually flood the largest area of floodplain possible in support of the flood-dependent livelihoods and ecosystems of the valley would be a wonderful tribute to her life's work. The dams on the Senegal River are an incontrovertible reality. The challenge lies in improving their management so as to minimise the negative impacts on the environment and allow a wider range of stakeholders to benefit from them. True integrated management might prove Adrian Adam's pessimistic pre-dam statement wrong (quote as translated by the author):

"Developing the resources of the Senegal River is an essential task for river people and for the riverine countries as a whole. However, were it to be done according to current plans, it would be better for them that it not be done at all".

Adrian Adams 1977. *Le long voyage des gens du Fleuve.* Maspéro, Paris.

Table of Contents

Acknowledgements

Core funding for the project was provided mainly by the Ministry of Development Cooperation of the Netherlands, through the IUCN Wetlands and Water Resources Programme, and by the French Global Environment Facility (FFEM). Additional support received by the Diawling National Park includes grants from the Government of Catalonia, the International Foundation for the Banc d'Arguin and the Convention on Wetlands (Ramsar, Iran, 1971). The Government and the people of the Islamic Republic of Mauritania supported the project in many ways. Scientific support was provided chiefly through a partnership between the Universities of Strasbourg and Nouakchott, but also by individual researchers and students from Mauritania, Mali, Senegal and France.The draft of this manuscript evolved toward its final form thanks to comments provided by Mike Acreman, Ger Bergkamp, Elroy Bos, Stéphane Bouju, Pierre Campredon, Mohamed Lemine Ould Baba, Jean-Yves Pirot, Ibrahim Thiaw and Piet Wit. Starr Pirot edited the original English version.

These contributions are all gratefully acknowledged.

Foreword

The Convention on Biological Diversity (CBD) has been hailed as one of the most effective instruments for conservation. It is, however, a complex document and one not easily translated into action. Amongst a plethora of technical documents, it advocates an ecosystem approach to environmental management, the principles of which it spells out (Appendix 1). However, for those around the globe who are responsible for implementing the Convention, applying these principles may be less than straightforward. IUCN has already produced a practical guide for decision-makers and conservation practitioners (Pirot *et al.,* 2000) which sums up lessons learned and provides guidelines on *"who should do what"* for successful ecosystem management. It provides summaries from a wide range of case studies to illustrate certain points.

This book, which tells the story of an ecosystem approach to the rehabilitation of the lower delta of the Senegal River in Mauritania, in and around Diawling National Park, is a companion volume to that guide. Its main objective is to provide practitioners with a *"feel"* for what the approach can entail in the real-life setting of a remote corner of the Sahel, where people's livelihoods are inextricably tied to the productivity of their delta. This productivity is in turn influenced by the mixing of fresh and saline waters during the floods, and by the surface area flooded.

Restoring the floods, not as an exact replica of the pre-dam situation, but largely based on the water requirements of the natural resources as perceived by the local communities, has been a daunting task. Local knowledge of pre-dam functioning was combined with technical advice from a wide range of experts to arrive at a consensus flood scenario aimed at enhancing both biodiversity and productivity, and this was then laid down formally in a management plan.

Rather than being a finished product, a management plan should be an ongoing process with constant adjustments in response to unforeseen alterations in the ecosystems, rapid changes in stakeholders' resource use strategies and unexpected institutional changes. Very few of these *"surprises"* feature in the logframes, which generally accompany projects. In the field, many decisions cannot be based on external guidance but must rely on local managers' (a category which encompasses protected area staff and resource users) growing understanding of how ecosystems function.

As former Senior Policy Officer for Rural Development and the Environment at the Royal Netherlands Embassy in Dakar, Senegal, I have followed the development of the Diawling project with great interest throughout its successive phases. The unquestionable success of the rehabilitation effort, both in improving local livelihoods and conserving and even enhancing biodiversity, has been achieved against a challenging environmental, social and institutional backdrop. The achievements and unresolved issues are presented and the project approach is compared to the principles for ecosystem management as established by the Convention on Biological Diversity. Some lessons are extracted and proposals to address a number of challenges are made.

Gertjan Tempelman
Head of Development Cooperation
Royal Netherlands Embassy
Dar es Salaam, Tanzania

1. Introduction

In the 1980s, the Islamic Republic of Mauritania declared the establishment of a protected area in the lower Senegal River delta (Figure 1) as a priority under the National Action Plan for the Environment. In 1989, as part of the *"Wetland management and rural development in West Africa"* project supported by the Government of the Netherlands, IUCN initiated a consultative process with the local communities, relevant government institutions and the river basin authority OMVS (Box 1). In 1991, these discussions resulted in the official creation of Diawling National Park. Subsequently, the park authority assessed the development priorities of the local communities, demarcated the boundaries of the protected area and began inventory work. In 1993, a field project was launched as part of the Dutch-funded regional programme entitled *"Strengthening institutional capacity to manage wetland resources in West Africa"*. The field project's aims were:

- to build the hydraulic infrastructure (embankments and sluice-gates) necessary to reflood the park and its surrounding areas.
- to design and implement a preliminary management plan for the area, including activities to promote sustainable development alternatives for the local communities in the buffer zone.
- to provide training in management and monitoring activities to the technical staff of the park.

The first issue the management plan of the park had to address was the rehabilitation of the degraded delta wetlands where the yearly floods (Figure 1) had ceased with the construction of Diama dam and the reservoir embankment. What had once been a productive complex of floodplains and pans had become an expanse of dry,

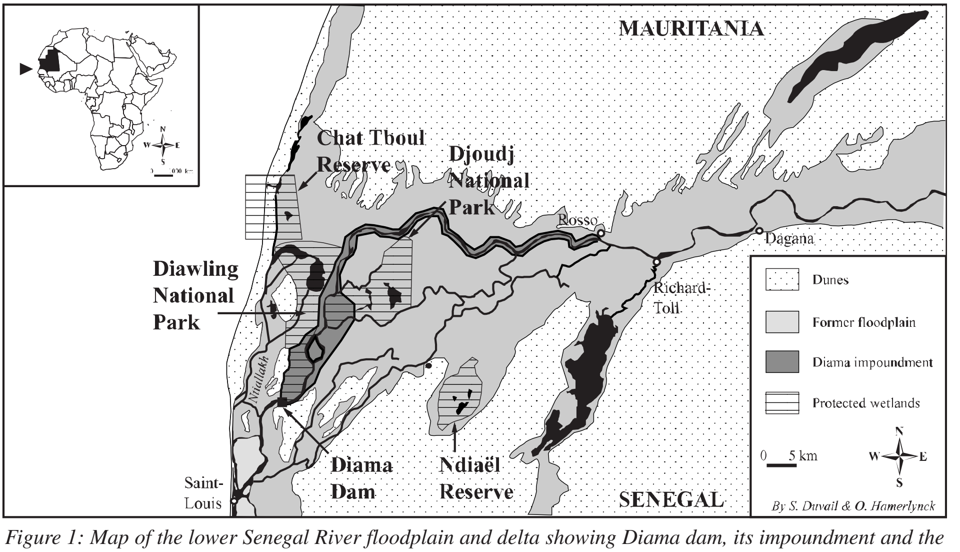


Figure 1: Map of the lower Senegal River floodplain and delta showing Diama dam, its impoundment and the protected wetlands, including Diawling National Park.

cracked clay interspersed with small dunes. The hot dry desert wind, obstructed only by greyish dwarf bushes, blew clouds of salt-laden dust across the landscape. Where thousands of pelicans and flamingos had fed there were now desert larks and sandgrouse. It was hard to imagine that the area had ever been a thriving wetland. The dam had also prevented the mixing of fresh and salt water, thus destroying highly productive estuarine and mangrove ecosystems. To restore these functions, water would have to be used to create an artificial estuary in the Ntiallakh basin by bypassing the dam and reflooding the park.

A subsequent phase of the field project (1996-2000) focused on the implementation of the management plan and the establishment of joint water management procedures with the park authority and the various stakeholders. The current phase (2001-2004), whose aim is to consolidate the successes of the preceding phases (ecosystem restoration and enhancement of local livelihoods), has also set the ambitious goal of creating a transboundary Biosphere Reserve. However, this ongoing phase is not within the scope of this book.

2. Background

2.1. From marine bay to (pseudo) delta

During the last major marine transgression (5500 BP), the delta of the Senegal River was a large marine bay, over 50 kilometres wide at its mouth and stretching 200 kilometres inland from the present-day coastline (Figure 2). As the sea receded and river sediments gradually accumulated, a patchwork of channels, floodplains and islands came into being. Under the combined influence of strong wave action and the longshore drift, a coastal sand bar evolved into a coastal dune, thereby closing off the bay.

Inland from this sandy ridge lies a vast low-lying floodplain (below 1.4 m ASL) with poorly drained saline soils. Several inland dunes (below 6 m ASL), whose origin is still the subject of scientific controversy (Duvail, 2001), emerge like islands from the plains. The largest of these are Ziré and Birette dunes (see Figure 5 page 12). Depressions in the floodplains are often below sea level: when the salty surface sediments lose cohesion during the dry season, wind erosion gradually wears the soils down to groundwater level. These depressions can hold water for several months after inflow from and outflow to the river have ceased, and the resulting temporary waterbodies attract large numbers of waterbirds.

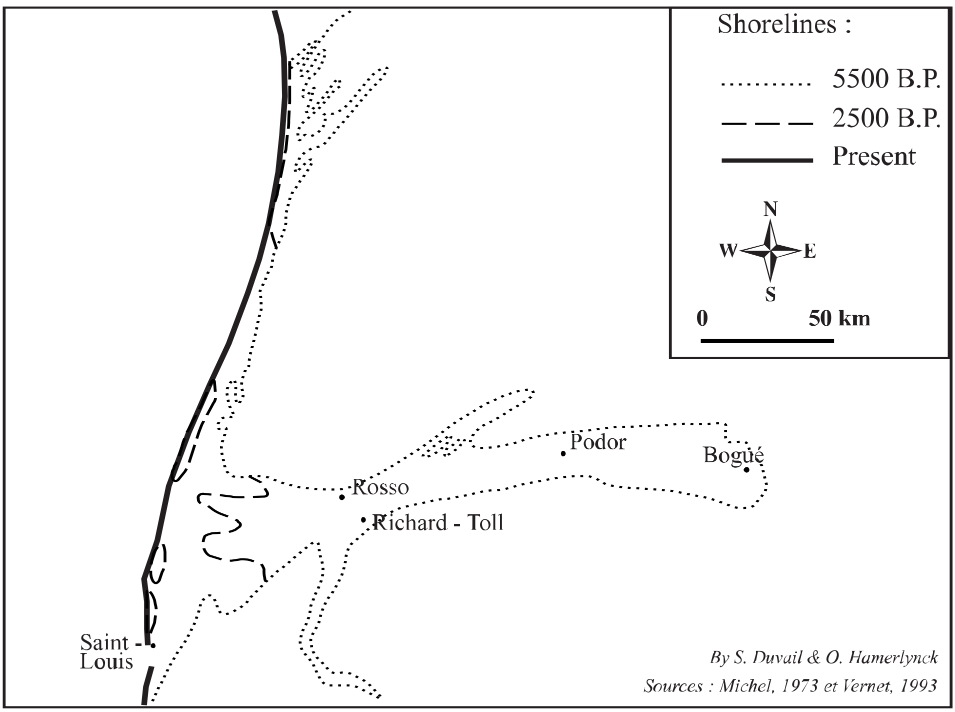


Figure 2: Evolution of the shoreline since 5500 BP.

The position of the main and subsidiary river mouths has shifted with the changing balance between river flows and oceanic forces. During periods of heavy flow, the river tends to breach the coastal dune along the east-west axis of the main river channel at Chat Tboul lagoon (Pictures 26-29), a channel which was still navigable in the late 18th century. During periods of low river flows, such as at present, marine sand seals off these openings. Another mouth existed a few kilometres north of Ndiago (Figure 5), and the main mouth has gradually moved from Saint-Louis island (where it was located when the city was founded in the 17th century) to its present position some 30 kilometres further south. During the dry season one can easily wade across, and the increasing height of the sandbar in the river mouth (Barusseau *et al.*, 1998) may be one of the factors contributing to increased flooding downstream of Diama dam during water releases. Normal or *"active"* deltas have multiple branches linking the river to the sea and riverborne sediment deposits accumulate, a phenomenon which causes them to *"grow"* beyond the coastline. Since the modern day river has no side branches with functioning connections to the Atlantic Ocean, and as there is no significant *"bulge"* of the delta seaward from the coastline, the Senegal River delta can be referred to as a "pseudo-delta" (Dubois, 1954).

2.2. A recently settled *"no-man's land"*

In contrast with Aftout es Saheli, the vast coastal depression to the north of the delta, no neolithic sites have been discovered to date in the Mauritanian lower delta (Vernet, 1993). The many major archaeological sites uncovered both on the coastal and inland dunes indicate human presence dating back at least five centuries. Since true nomads use animal skins for storage, the seven distinct pottery types on Ziré dune suggest long periods of sedentary human occupation in different phases (Vernet, 1997). It is likely that these phases are related to the shifting ocean/river dynamics, with each period offering a different set of exploitable ecosystems. Many of the sites were occupied by groups which fed on butterfly shells (*Donax rugosus),* bivalves typically found on exposed sandy beaches. This suggests that the inland dunes were part of the coastline during that period. The more northern sites contain the blood cockle, *Anadara senilis*, an indicator of productive lagoon habitats. Sub-fossil mangrove oysters are abundant at Chat Tboul, which may have resembled the present day Siné Saloum estuary on the border with the Gambia (see Figure 4 page 7); their presence is a clue to how climatic zones in the Sahel shifted several hundred kilometres southward during the previous millennium.

From the late Middle Ages, a Wolof Kingdom ruled over most of the delta, establishing its capital on what is now the Mauritanian bank (Barry, 1985). Then, in the 17th century, the delta was beset by strife. The new colonial power (the

Kingdom of France) attempted to establish control, in a seesaw pattern of expansion and contraction, while various factions of the Wolof aristocracy fought to gain control of river trade (slaves, ivory, gum arabic, salt). A third entity was the newly formed Moorish Emirate of Trarza, the result of a thirty year war ending in the victory of the Arab Beni Hassan warrior tribes over the maraboutic tribes of Berber origin. None of these political entities was particularly stable, least of all the Emirate which was plagued by incessant infighting and a rapid succession of rulers. Destructive raids by the Moors were frequent on the Senegalese bank and prompted the French to embark upon the *"pacification"* of Mauritania in the early 20th century. The violent history of the delta continued to surface as late as the 1930s when a bloody conflict raged between the Tandgha and Idiawadj tribes over fishing rights in the Ntiallakh (Duvail, 2001).

For many centuries the lower delta was thus a rather insalubrious "no-man's land" (Schmitz, 1990), used chiefly by nomads (mainly the Moorish tribes of the Trarza dunes) as dry season grazing for cattle and camels coming from as far north as the Spanish Sahara. Only three groups were permanent dwellers in the delta, one of which, the Takhrédient fishermen (freed slaves or *"Haratin"* belonging to a small but fierce warring tribe) are considered to be the first settlers. The second, made up of renegade Haratin groups living in Birette and Ebden, guarded the cattle of the Saint-Louis colony. Finally, a few Wolof villages grew up under the protection of the expanding colonial power. Originally their inhabitants lived on rainfed and recession agriculture but gradually converted to marine fisheries after World War II. The scarcity of human population during the wet season is illustrated by Baillargeat (1964), who laments the hardship he endured while studying the hydrology of the area during the floods from 1961 – 1963, *"there was not a single person in any of the villages to cook me a meal!"*

After independence, the lower delta was gradually settled by sedentary dwellers, predominantly Haratin. They derived their income mainly from the small street-corner shops they kept all over Senegal. The Moorish tribes, whom necessity had driven to keeping small ruminants, also settled more or less permanently, reducing their wet season migration range, which formerly spanned up to several hundred kilometres, to less than 20 kilometres.

2.3. Three weeks of green and a dam

The lower delta is located in the Sahel, a wide band which stretches across Africa from the Atlantic Ocean to the Red Sea at the southern edge of the Sahara desert. The Sahel is the pastoral zone between the true desert (with less than 150 mm annual rainfall) and the area where rainfed agriculture is possible every year (over 400 mm annual rainfall). Although much smaller, the Senegal River resembles the Nile in that its waters derive from mountainous areas with high rainfall and then flow northward into the dry lands of the Sahel, where they seasonally flood expanses of rich alluvial soils. The river floods are a lifeline for the sedentary populations, whose traditional livelihoods are recession agriculture and fishing, and for the nomadic livestock keepers who use the stubble fields and pastures for grazing during the dry season.

After years of relatively abundant rainfall (an average of 370 mm/yr in Saint-Louis from 1931 to 1960) between July and October, the lower delta now has a shorter rainy season with only a few heavy, localised downpours between mid-August and mid-September. Because of extreme outliers, average annual rainfall is not very meaningful (e.g. 37 mm in Rosso in 1983, sufficient for grasses to germinate but not to sustain their growth!). It is generally felt that there has been some improvement since 1994. In addition to total yearly rainfall, the rainfall distribution pattern is also very important. Nearly ideal rains (from the livestock keepers' point of view) occurred in 1998: 30 to 40 mm showers every two to three weeks, adding up to a total of about 200 mm. These are the kind of rains that produce maximum herbaceous biomass on the dunes, which turn a lush green for just a few weeks a year. Since 1994, a series of years with higher than average annual rainfall (Figure 3) has facilitated the regeneration of the *Acacia tortilis* savannah. An experimental exclosure, which provided three years extra protection from livestock, yielded spectacular results (Picture 20 to 23), illustrating the resilience of Sahelian ecosystems.

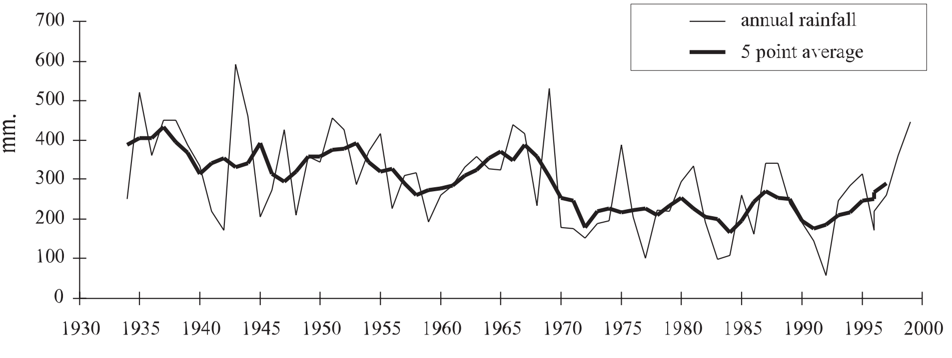


Figure 3: Annual rainfall at Saint-Louis (25 kilometres south of the study area).

Nevertheless, with evaporation (1.8 m at Saint-Louis, 2.2 m at Rosso) at approximately ten times total annual rainfall, most of the greenery of the lower delta was flood-dependent. This was true of the *Salicornia* saltmarshes and the patches of mangrove along the Ntiallakh estuary, the vast expanses of perennial grasses and sedges on the floodplains, the wild rice and water lilies in the least saline depressions, the rows of *Tamarix* on the sandy levees of the watercourses and the *Acacia nilotica* woodland on the heavier soils at the dunes' edges. Obviously, the rest of the food chain (microorganisms, fish, reptiles, birds, mammals and humans) were also flood-dependent.

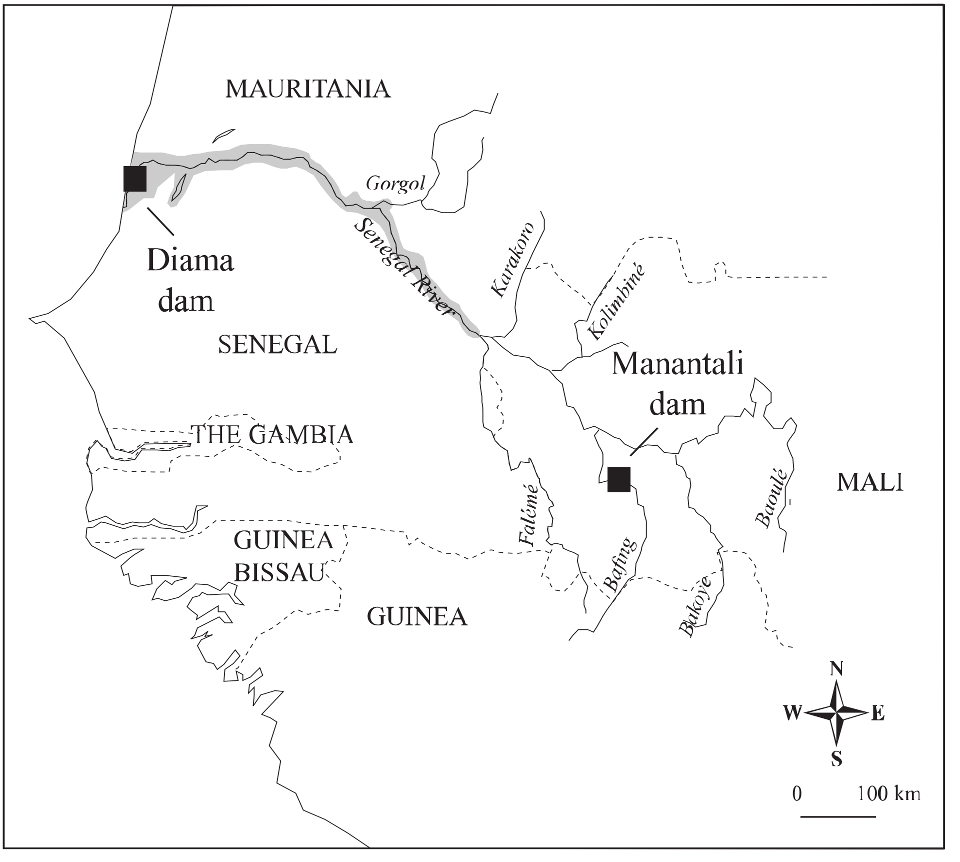


Figure 4: Map showing the Senegal River Basin and the location of the two large dams built for OMVS.

The dam at Diama (Box 1) was commissioned, and in 1990 the reservoir embankments were completed, putting an end to the beneficial effects of flooding for the entire Mauritanian lower delta. In 1989, a crisis stemming from the land reforms carried out to convert the Senegal River floodplain to irrigated farming land (Box 1), resulted in a protracted stand-off between the armies of the two riparian countries entrenched on either side of Diama dam. For the communities of the lower delta, the closing of the border (until 1993), the loss of their shopkeeping livelihoods and the repatriation of a large number of Mauritanians who had been living in Senegal, exacerbated the effects of the ecological crisis. As a result, most of the able-bodied men migrated to the regional capital (Rosso), the national capital (Nouakchott) or the fishing port of Nouadhibou. Women, children, the elderly and the disabled were practically the delta's only residents.

Box 1: Organisation pour la Mise en Valeur du fleuve Sénégal

In the 1960s, the four countries of the Senegal River basin, Guinea, Mali, Mauritania and Senegal founded the OERS (Organisation des états Riverains du Sénégal) with the aim of planning the sectoral development of the basin. The organisation quickly lost momentum and disbanded when Guinea pulled out. In 1972, the three remaining nations revived the agreement under a new title, OMVS (Organisation pour la Mise en Valeur du fleuve Sénégal). The new organisation devised a plan to solve the food crisis that hit the Sahel in the 1970s and 1980s through intensive irrigated rice production on 375,000 ha of floodplain land.

As a result, two major dams were built on the Senegal River at a total cost of $US 800 million (Figure 4):

- Diama dam in the delta (completed in 1985). Designed to stop the dry season influx of seawater into the lower valley, it has gradually been converted into a storage reservoir, where water levels are maximised in order to reduce irrigation pumping costs. This has led to the colonisation of the reservoir by invasive plants *(Typha domingensis, Pistia stratiotes, Salvinia molesta)* and to a rise in saline groundwater levels on the adjacent riparian land.
- Manantali dam on the Bafing river (a tributary of the Senegal) in Mali (completed in 1989). The impoundment stores up to 11 billion m^3 of highly seasonal runoff from the Fouta Djalon mountains in Guinea, the intention being to release the water for irrigation, to make the river navigable from the ocean to Kayes and to produce hydropower. In order to enable traditional recession farmers to adapt to the new situation, managed water releases, intended to flood at least 50,000 ha, were planned for a transition period of ten years. Although the floods have failed to achieve the intended results, mostly because of erratic management of the reservoir and the failure to time the releases to coincide with the floods from the other tributaries (Hollis, 1996), they have reduced the negative environmental and social impacts of the dam. Managed flood releases have been continued to date but it is feared that as hydropower production becomes the dominant use they will eventually be phased out.

By 1997, only 100,000 ha had been equipped for irrigated agriculture, and only 44,000 ha were farmed in the end because of loss of soil fertility and increased salinity (OMVS *et al.*, 1998). With average yields of around 3 T/ha/year, instead of the 12 tonnes targeted, irrigated agriculture in the valley appears as neither economically viable nor ecologically sustainable. Hydropower production started in 2002. Today, in 2003, no investments have been secured for the navigability scheme. However, the negative impacts of the dams on fisheries (Bousso, 1997), the environment, and human (Verhoef, 1996) and animal health (Mulato, 1994) have been considerable and the livelihoods of the valley's inhabitants have been seriously affected (Salem-Murdock *et al.*, 1994, Adams, 1999).

It is therefore easy to understand that the announcement of the plan to include a part of their land in a National Park, which, according to their only other similar experience, i.e. Djoudj National Park in Senegal (Box 2), would mean restrictions on resource use, was not warmly welcomed. In the words of one of the villagers, referring to the decline in natural resources since the construction of Diama dam and to the expected ban on the use of resources inside the boundaries of the protected area: *"first they put in a dam to kill us, and now a park to finish us off"*.

Box 2: Djoudj National Park

In 1971, the Republic of Senegal established Djoudj National Park on the Senegalese bank of the river just opposite the Diawling (Figure 1). Initially, the park covered about 10,000 ha of interconnected depressions on saline soils quite similar to the Diawling - Tichilitt basin on the Mauritanian bank.

At the time, conservation action in many parts of Africa emphasised exclusion and perceived local resource users as potential trespassers, based on the paradigm that species protection could only be achieved by barring humans from certain areas. Thus, the Djoudj was initially set up as a *"bird sanctuary"*. Traditional fishing grounds were off limits and none of the natural resources could be harvested. Any livestock venturing into the park could only be reclaimed after payment of a fine. When the park was expanded to 16,000 ha in 1976, some of the buffer zone villages were resettled. The approach was effective inasmuch as the park remained a haven for biodiversity and virtually the only area in the delta where ecosystem functions were maintained throughout the various crises.

The Senegal River is a political boundary, but for the local communities it has always been an easily navigable link between the two banks. The tribes and ethnic groups of the lower delta maintain close ties across the water and the tension caused by the protected area on the south bank was common knowledge on the north bank. The impending creation of a protected area on the north bank was thus greeted with strong misgivings. A great deal of time and effort were spent explaining that there was a new breed of protected area managers who considered local communities and their sustainable resource practices as aids rather than threats to conservation.

It should be emphasised that in 1993, Djoudj National Park initiated a similar participatory and conciliatory approach. A portion of the products from the ecosystems and the benefits stemming from tourism are now shared with the local communities, living standards in the buffer zone have improved considerably and the park enjoys strong local support.

Picture 1: The multidisciplinary team during a wrap-up session after a day in the field, March 1994.

3. The story

3.1. A National Park on paper

When Banc d'Arguin National Park was established in northern Mauritania in the 1970s, the Mauritanian authorities announced their intention to create a second protected wetland in the south, covering most of the Senegal River delta. Livestock keepers successfully lobbied for the carving out of the important pastures of the Ntiallakh basin (Figure 5) from the protected area, and the whole idea was more or less shelved until environmental impact studies for Diama dam were carried out (Gannett *et al.,* 1980). In order to partially compensate for the environmental losses that would result from the building of two large dams on the Senegal River (Figure 4 and Box 1), a proposal was made to create an artificial estuary in the Ntiallakh basin (Figure 5). The establishment of a protected area similar to the Djoudj (Box 2) was advocated as the most effective type of land use for the extremely saline soils of the lower delta.

After much controversy, Diawling National Park was finally created by presidential decree in January, 1991. It covers 16,000 ha along the Mauritanian bank of the Senegal River and its stated aims, developed with support from IUCN, are:

- to preserve and ensure the sustainable use of the natural resources of a part of the lower Senegal delta ecosystem;
- promote the continuous and harmonious development of the range of activities of the local population;
- co-ordinate pastoral and fishing activities within its boundaries.

These decidedly avant-garde objectives provided the protected area authority with a clear mandate to integrate conservation and development and to involve all stakeholder groups in the entire lower delta, not just those whose traditional rangelands were inside the protected area. Fortunately, the park had some young and enthusiastic staff members who set out to explain its aims to the generally hostile local communities. Furthermore, the park's technical staff did not wear uniforms and there were no formally trained guards. Instead, it recruited some respected villagers, mostly elders selected by the local community, as 'surveillants'. Unfortunately, by this time there were not many resources to protect or use, sustainably or otherwise. In 1990, a low rainfall year, the flood on the Bafing (Figure 4), such as it was, was used to fill Manantali reservoir in Mali and little or no water was released from Diama dam. Consequently, the salt water downstream was not diluted and towards the end of the dry season, in May, 1991, the Ntiallakh was over three times saltier than the ocean (Box 4). As fate would have it, the May and June spring tides were particularly high that year and brine covered the low lying areas, laying waste to the remaining *Sporobolus* grasslands,

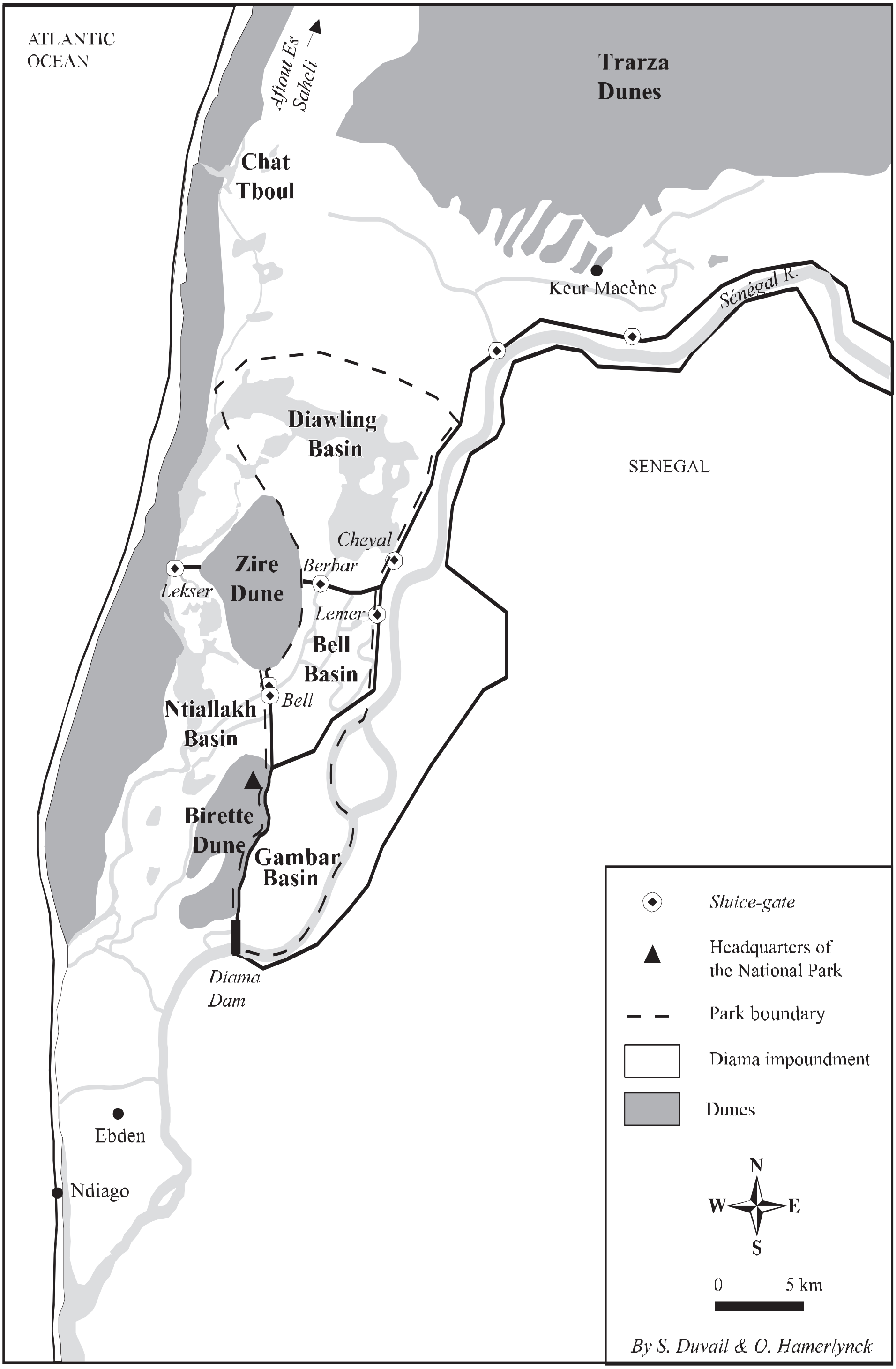


Figure 5: Map of the Mauritanian bank of the lower Senegal River delta showing the main geomorphological features and Diawling National Park with its three basins, from north to south: Diawling, Bell and Gambar.

killing the hardy *Tamarix* and destroying most of the mangrove remnants that had so recently provided nesting sites for 12,000 pairs of piscivorous waterbirds (Naurois, 1969). The contractor, who was working hard to complete the Diama embankment before the rains, even had to build emergency levees against the intrusion of seawater.

Two intrepid birdwatchers, having completed their annual midwinter census in Djoudj National Park and hoping to impress ornithological circles with the first counts from the newly established park in Mauritania, ventured across the border in January 1993 and 1994. It was to be one of the most frustrating experiences of their careers. In January, 1993 (thanks to the 1992 flood, see Table 3, page 36) about 2,000 waterbirds were observed in the Mauritanian lower delta but only 18 of them were inside the park. In January 1994 (1993 flood), the situation was even worse, with exactly three waterbirds seen in the park, although in total some 5,000 were counted in the delta (Table 3). The visitors were right to wonder why *"a dusty salt desert with a few sickly-looking cows"* should be designated as a National Park (Triplet & Yésou, *in* Taylor, 1994). It was under these admittedly less than auspicious circumstances that the IUCN field project to assist in the design and implementation of the park's management plan, began in September, 1993.

3.2. The management plan

After a few months of work to set up contacts, management structures and communication systems, the fieldwork began in earnest in March 1994 with a multi-disciplinary team comprising representatives of the local communities, park staff and a line-up of sociologists, hydrologists, agronomists, ichthyologists, protected areas specialists, a botanist and an estuarine ecologist (Picture 1). From interactions with the different user communities it was clear that local knowledge on the pre-dam functioning of the system was extensive, and would indeed be invaluable for the drafting of the management plan.

The study concluded that the first step was to restore the pre-dam flood cycle by building the necessary sluice-gates and embankments. The working assumption was that ecosystem productivity, which seemed to have been almost entirely flood-dependent, would allow the local communities to resume their traditional activities of fishing, gathering and livestock keeping and to develop new ones, such as ecotourism and market gardening. The multi-disciplinary team's findings largely confirmed those of the project identification missions initiated in 1989, the only exception being that, in the view of the local fishermen, two extra sluice-gates were needed to ensure that fish and shrimp migrations between the basins could take place.

Other needs were expressed for which no provision had been made in the project, including measures to provide an adequate drinking water supply and to facilitate transport by building access roads and embankments. It was therefore decided to increase the width and height of the Lekser embankment in order to allow vehicles to access the coastal dune year round. The extra cost of the infrastructure added or modified in keeping with the wishes of the local communities meant that only four of the planned fifteen kilometres of the northern embankment could be built, and that the Hassi Baba sluice-gate would not be installed at all (Figure 6). Once all the other infrastructure was completely operational, particularly the Cheyal sluice-gate, the maximum water level that could be reached in the Diawling basin would be tested and the need to complete the northern embankment and Hassi Baba sluice-gate would be re-assessed (Hamerlynck, 1997).

Theme 1: Restoring hydrological functioning and natural resources	**Theme 2 : Managing Diawling National Park**	**Theme 3 : Community development**
1 – Restoring hydrological functioning 1.1 – Establish a hydraulic calendar which allows ecological functions to reproduce the pre-dam situation 1.2 – Improve the knowledge base on the hydrology of the lower delta	**1 – Optimising Diawling National Park management** 1.1 – Streamline the DNP organisational chart 1.2 – Provide field infrastructure, equipment and budget 1.3 – Develop a detailed land use plan based on environmental values 1.4 – Organise surveillance of the park and the protection of its natural resources 1.5 – Develop internal communication (reporting, etc.) 1.6 – Establish a technical and scientific committee 1.7 – Develop partnerships with research institutions	**1 – Strengthening traditional resource use practices which are compatible with ecosystem restoration** 1.1 – Improve the quality and marketing of artisanal produce 1.2 – Improve horticulture and the marketing of horticultural products 1.3 – Improve fish production and marketing
2 – Restoring the typical vegetation of the lower delta, fixing the dunes and protecting embankments 2.1 – Restore the woody vegetation: floodplains, estuary, dunes 2.2 – Restore the herbaceous cover: perennial, annual		**2 – Developing new activities compatible with ecosystem conservation** 2.1 – Develop ecotourism 2.2 – Develop hay production 2.3 – Test small-scale aquaculture 2.4 – Test beekeeping 2.5 – Remedy the lack of vessels for fishing, transport and tourism
3 – Restoring fisheries potential		**3 – Improving the quality of life of local communities** 3.1 – Find an appropriate solution to the drinking water problem 3.2 – Find an appropriate solution to the road access problem
4 – Restoring ornithological values		

Table 1: Summary of the operational objectives of the management plan.

During the rest of 1994 and 1995, in-depth interviews were conducted with most of the stakeholder groups and additional scientific investigations were carried out by park and project staff, mostly in collaboration with the new Faculty of Sciences at Nouakchott University. In early 1996, the information thus gathered was used to produce the first draft management plan. It contained a descriptive section which reconstructed the pre-dam situation from the literature, from interviews with perceptive resource users and from observations of the 1994 and 1995 floods, and an operational section containing the aims (Table 1), activities and indicators grouped under three different themes.

This draft was then circulated among the local partner institutions (Nouakchott University, Banc d'Arguin National Park, Djoudj National Park, appropriate departments of several ministries). The second draft was submitted to a broad group of stakeholders and government institutions in December, 1996 and, after amendment, approved by the Ministry of Rural Development and the Environment in early 1997.

3.3. Gaining local credibility

There were good reasons to assume that the key species, adapted as they were to the local conditions of prolonged drought, erratic rainfall, highly variable floods and extreme salinity fluctuations, would be fairly hardy. However, there was still a great deal of uncertainty as to how they would react under the new artificial conditions of managed flood releases into embanked basins with only a few interconnections regulated by sluice-gates.

Setting up the hydraulic infrastructure would also obviously take time: heavy machinery can only access the low-lying areas between March and the first rains in August, and the unstable deltaic soil required careful and lengthy preparation before it could bear the weight of the embankments and sluice-gates.

It would therefore be unethical and also politically risky to expect the stakeholders to sit out the environmental and socioeconomic crisis and wait for the ecosystem restoration project to (hopefully) pay off.

3.3.1. Onions and tomatoes

On the basis of the priorities listed by the local communities, it was thought that horticulture could yield immediate benefits. Under the project's auspices, the local women organised themselves into market gardening associations. These groups were provided with some wire fencing, simple tools and seeds in quantities depending on the number of paying members and the surface area to be cultivated. Needs were assessed for each village and the support took different forms. Thus, one village was provided with cement for a well, and the women contributed to purchase the iron reinforcements and the services of professional well diggers (Picture 2).

Picture 2: Vegetable garden in Kaharra (on the costal dune). The cement for the well was contributed by the project.

For the first six months, technical advice was provided by an agricultural extension worker. The results of the 1994 campaign were a bit disappointing, as the textbook techniques had to be adjusted to deal with the sandy and salty soils of the dune edges. In the second season, when the women were on their own, except for some follow-up visits to check on bottlenecks, the area, especially Birette where fresh water from Diama reservoir was available all year, became a major exporter of vegetables to Nouakchott.

The collective undertaking suffered a blow when the Birette co-operative was driven out of its original garden by a man who had moved to Nouakchott but then suddenly *"remembered"* that his ancestors had cultivated that very same spot. Some of the more entreprising women individually developed new gardens and started employing foreign workers on a sharecropper agreement. Much more land was developed by outside investors and by members of the different government departments and security forces present in the delta. However, the seeds of self-confidence had been sown, and when the vegetable markets were saturated in 1998 and 1999 (the horticulture fad having been taken up by communities and donors countrywide), the same astute women turned up at the National Park's sluice-gates. In the evening they would pay the fishermen in advance for the night's catch, then spend the night on the spot and export the fish to Senegal at sunrise. The traditional traders, who arrived by car from Rosso a few hours later, had to make do from then on with small fish and less valuable species.

In the other villages, especially on the coastal dune, horticultural activities were not so successful economically, mostly because of the limited freshwater supply. Nonetheless, this starter activity with no clear link to the rehabilitation scheme or to conservation, opened communication channels between the extremely committed park authority and the communities. In this respect it had a huge positive impact.

Another scheme, which temporarily created employment for members of the local community, was the building of the park headquarters at Bou Hajra. It was hoped that the use of woodless construction techniques, as taught by Development Workshop (winners of the UN Habitat Prize in 1998) would improve building and architectural standards in the delta (Picture 3). Funded by the Provincial Government of Catalonia (Spain), the construction project provided much needed dry season income to many workers, especially to the Takhrédient fishermen from Ziré. The year-round presence of this capable and dynamic component of society is thought to have been a positive element in community organisation and decision-making.

Picture 3: The Park headquarters was built using a "woodless" construction technique.

Although the woodless construction technique did not catch on in the delta, mainly because suitable non-salty clay was hard to find, it did generate spin-offs in the central valley. A group of refugees returning home via Diama dam saw the construction site and were interested. During their long exile, the *Acacia nilotica* stands around their villages had been cut and used to produce charcoal, and there was now a shortage of the termite-resistant wood traditionally used in construction in their area. They volunteered to help with the building in order to learn the woodless construction techniques, and when they returned home they started a building programme that is still spreading around Boghé.

In summary, the starter activities proved very useful as a way for park managers and the communities to get acquainted, but ecosystem rehabilitation remained the primary tool for improving local livelihoods.

3.3.2. Upstream - downstream hydraulics

Following on from the Diama impact assessment, it had been calculated that total inflow of 45 cubic metres per second (cumecs) would be needed in the lower delta: 20 cumecs at Cheyal for the northern Diawling - Tichilitt basin and 25 cumecs at Lemer for the Bell basin, 18 cumecs of which would be needed to supply the artificial estuary (Figure 6). When the project started, only the Lemer sluice-gate had been completed, and its capacity was only 15 cumecs. It was used for the first careful experimental reflooding of Bell and Diawling basins in the summer of 1994.

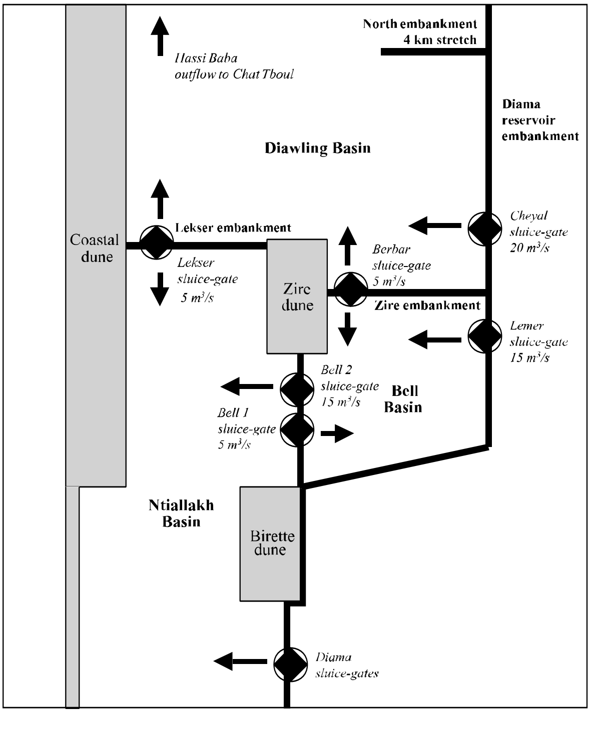


Figure 6: Hydraulic infrastructure as operational in 1999.

The same year, the first reasonably large flood was released from Manantali since its completion in 1988. The operators of Diama, whose prime concern is to maintain a high, stable water level in the reservoir to reduce pumping costs for irrigation upstream, had not lowered the water level in anticipation of that flood. Moreover, the arrival of the flood coincided with a local thunderstorm that turned out to be the heaviest rainfall event ever recorded in Mauritania (181 mm in 12 hours). When the water level in the reservoir peaked, the operators panicked and made an emergency release. This created a wave which swept away the original Lekser embankment built by the army during the 1989 crisis and flooded the city of Saint-Louis in Senegal. It contributed substantially to filling the Diawling-Tichilitt basin, and even flooded Chat Tboul. The Takhrédient and park staff worked together day and night, filling sandbags to save the Bell embankment from being topped by the flood.

The 1995 flood was even more substantial (because there were qualms about the stability of Manantali dam). Fortunately, it was well managed at Diama, where the level had been lowered as a precaution. Maximum water levels reached in the lower delta in 1994 and 1995 were moderate (Table 2 page 35) and were in fact predominantly due to the releases from Diama, with experimental releases through the Lemer sluice-gate contributing only early in the season. In that sense, the pilot releases were not a true test of the effectiveness of the project infrastructure. Still, the natural resources reacted very positively to the return of the floods and two activities immediately took off again, namely fishing (Table 3) and *Sporobolus* gathering for mat weaving (see Picture 7 page 33).

In 1996, a low rainfall year, Diama (where the operational level went from 1.5 m ASL to 1.9 m ASL) released very little water, creating another resource crisis in the Ntiallakh and Diawling basins. However, in the Bell basin, which now had its complete hydraulic equipment, a test of the managed flood release was possible independent from Diama's influence. In order to protect the new embankments from erosive wave action while awaiting the regrowth of vegetation, it was decided that the water level should remain well below the maximum (1.40 m ASL) provided for by the management plan (see Table 2). The maximum level was in fact not reached until 1999.

3.3.3. Conflict and compromise

Though hostile to the park as an institution, the Takhrédient fishermen could see the potential benefits of the ecosystem rehabilitation scheme proposed by the project. Like the other communities, they were convinced that park and project staff were being nice only to more smoothly establish themselves and that *"as soon as the birds took over"* the locals would be told to leave. Still, they enjoyed discussing fish behaviour and the hydraulics of the natural system.

Perhaps because of their fierce warrior past, they felt less insecure about land tenure than the other tribes and were therefore less afraid to enter into an alliance, knowing they could always turn against the project and win.

They allowed the project to proceed on the condition that they always be informed of any activity on *"their"* land. When a team of topographers wanted to install stageboards but had omitted to inform the village, it became clear that they meant what they had said. Each morning the bewildered team would find its benchmarks removed. Thinking that this was perhaps a children's prank, they tried twice to place the benchmarks, pour the concrete and install the stageboards all in one day, only to find gaping holes the next morning. When the misunderstanding was cleared up and the park authority had apologised, the work went ahead unimpeded.

In 1995, the fishermen, who had been provided with a revolving fund for purchasing fishing gear, sold at least 15 tonnes of fish and were on the whole quite pleased with the project. Interestingly, they abandoned their traditional individual fishing zones to concentrate their efforts near the park's hydraulic works, where fish tended to congregate (Picture 4).

Picture 4: Fishermen checking their nets in front of the Cheyal sluice-gate. As soon as the hydraulic infrastructure became operational, fishermen abandoned their traditional individually 'owned' fishing areas and developed a rotation system for setting their nets at the sluice-gates.

A more serious incident with the Takhrédient occurred when the Berbar sluice-gate was completed in 1996. The Takhrédient realised then that the five kilometre Ziré embankment would only be suitable for walking or cycling. The project team had explained many times that the extra cost of an embankment like the one at Lekser - where the extra width was justified because it provided the only motor vehicle access to the dozen or so villages of the coastal dune - could not be justified for a single village of 200 inhabitants. Maintenance costs would be prohibitive, the activity requiring road access took place at the sluice-gates on the Diama embankment and the village was always accessible from the main road via the Bell embankment. Moreover, a major road through the middle of the park would be ecologically unsound and would complicate surveillance. In retaliation, the villagers fenced off the Berbar sluice-gate and refused to let it be opened. It should be recalled that the sluice-gate had been built at their own request to enable the fish to move from the Bell basin to their favourite spawning grounds in the Diawling basin. In fact, the project was not aware that a member of the park staff had promised vehicle access. It took more than a month of apologising and many meetings with tribal chiefs and high-level officials to dissipate the distrust.

Picture 5: Construction of the Lekser sluice-gate. This was one of two sluice-gates added to the original scheme on the advice of the local fishermen.

4. Toward a consensus

4.1. Hydraulic modelling

Initially, the managed flood releases were conducted on a trial and error basis. Sluice-gates were opened in 5 cm steps and water level, water quality and the progress of the flood through the watercourses and on the floodplain were monitored. Sluice-gate aperture was adjusted in order to match the observed water levels with the hydrograph set out in the management plan. In addition, a monitoring system was set up to collect meteorological, hydrological, chemical, biological and socioeconomic data, and the effects of each flood were analysed, including the perception of its *"quality"* for the various stakeholders.

From an early stage, it was felt that the development of a computer model of the *"new"* hydraulics of the artificial system, making it possible to simulate various flood scenarios and their effects on natural resources, would be a vital tool for the successful implementation of the management plan.

Describing the correlations between the hydrological changes and the responses of both the ecosystems and the socioeconomic systems required an ambitious programme of data collection across various disciplines using a holistic approach. This was achieved through a partnership with the *"Groupe de Recherche sur les Zones Humides"* (GREZOH), the Wetlands Research Group established under the auspices of the newly created Faculty of Sciences of Nouakchott University. Many European researchers and students were also involved. Data were collected primarily during 18 months of intensive fieldwork spread over flood and dry seasons from 1996 to 1999 (Duvail, 2001).

Water levels were recorded upstream and downstream of the inflow and outflow sluice-gates. Daily records were obtained from the most accessible sites. For the more remote sites, recording frequency varied from daily to weekly. To establish the rating curves for the different sluice-gates, over seventy flow measurements were carried out using an Ott C31 current meter.

Climatological data were obtained from an automatic weather station installed at the National Park headquarters in 1997. This recorded air and soil temperature, wind speed and direction, rainfall, relative humidity and solar radiation. Evapotranspiration was calculated for that station using the Penman (1948) formula, and a correlation was established with the *"class A"* pan records from Saint-Louis airport weather station in Senegal, about 25 km away.

Topographical data from two sources were combined. A 1:20,000 base map, dating back to 1985, was available (Bocande & Bouette, 1985). It had been established by closed loop traverse using a theodolite and provided altitude at points 200 m apart with a precision of 0.1 m. Wind-driven erosion and deposition are strong modelling forces on the salty floodplains which had been dry and without vegetation, except for a few temporary rainfed depressions, throughout the better part of the period from 1986 to 1994. Consequently, the morphology of many of the former floodplain channels had been considerably altered. Additional altitudinal measurements were therefore recorded in June, 1999 using a Mira Z differential Global Positioning System (GPS). This survey focused on the channels but also updated information on the depressions and the floodplain. Simultaneously, altitudes were recorded with 0.1 m precision for all hydraulic equipment, stageboards, data loggers, piezometers and a series of wells. All data were digitised and incorporated into a Digital Elevation Model (DEM).

Hydraulic modelling comprised a simple water balance model and a hydrodynamic model (Figure 7).

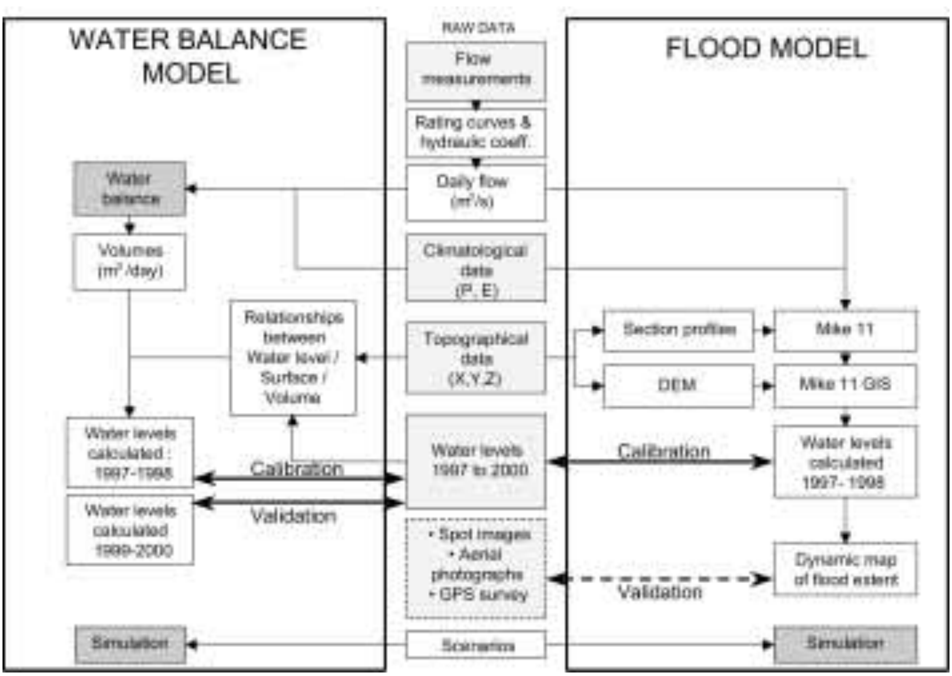


Figure 7: Hydraulic modelling framework.

The water balance models for the basins were drawn up on an Excel spreadsheet using a daily step based on the following equation:

$$Q_i + P + R - Q_o - E - I + \Delta St = 0$$

with

Q_i = Daily inflows in m^3 at sluice gate

P = Daily rainfall for the basin area in m^3

R = Daily runoff in m^3

and

Q_o = Daily outflows in m^3 at sluice gate

E = Daily evaporation in m^3

I = Daily infiltration in m^3

+/- Δ St = Daily storage variations in m^3

As the Bell basin is relatively small and characterised by swift flood propagation, the water level rapidly reaches an equilibrium which can be recorded at any of the basin's stageboards. Thus the model provides accurate predictions of water levels. Since both the Diawling and Ntiallakh basins are much larger, it was more difficult to establish a relationship between the observed water level and the surface area flooded. For these two basins, a daily water balance model was applied. This provides accurate predictions of water volumes but not of water levels. Because of the significance of the spatial distribution of water depth and flood duration for natural resources, it was deemed necessary to develop a hydrodynamic model by incorporating the hydrological data into MIKE 11 (DHI, 2000). In a second step, the resulting calculations were merged with the Geographic Information System (GIS) data. This combination of a simple one-dimensional hydraulic model and the Digital Elevation Model makes it possible to develop two-dimensional flood maps with flooded area, flood duration and water depth as outputs.

It is important to point out that the models (Duvail *et al.*, 2002a) were only completed after the project phases reported on herein had been concluded. However, the need to collect data for the development of the model mobilised many stakeholders and stimulated debate about the optimal flood release scenario. As is often true, the process turned out to be more important than the product. The model development process offered a collective goal toward which all involved, resource users, park staff, researchers and students, could contribute by supplying data. It provided a forum for discussing the impacts of the flood releases with people from a wide range of educational backgrounds and resource interests (Duvail & Hamerlynck, 2003).

4.2. Predicting resource response to managed flood releases

Georeferenced data, with an emphasis on the resources important to the local communities, were collected. Data on vegetation, fish production, waterbirds (important for tourism) and various resource use strategies and calendars were collected (Duvail, 2001). With respect to vegetation, the focus was on the distribution, biomass and nutritional quality of the annual and perennial plants grazed by livestock. The main species used in artisanal production, *Sporobolus robustus* for mat weaving and *Acacia nilotica* seedpods for hide tanning, were also monitored.

Subsequent to the 1994 flood release, a vegetation map was drawn up using a mixed vegetation cover and species dominance index (Boudet, 1984) and permanent monitoring plots were demarcated. The map was updated after each flood season. In 1998, landscape units were defined on the basis of geomorphology, soil characteristics and vegetation. The edges of these units were georeferenced in the field using GPS.

Beginning in 1996, the following data were recorded during the fishing season (October-February): the number of active fishermen, the total catch per species, fishing gear used, number of hours of fishing and catch value. Monitoring frequency was dependent on fishing intensity, *i.e.* every two days during the period of heaviest fishing activity, just after the sluice-gates were closed. The results are expressed as income per fisherman per day during the fishing season.

For waterbirds, the annual African waterfowl census data were used. These counts take place in mid-January and have included the Mauritanian delta since 1993. The numbers are correlated to the previous year's flood.

The hydrodynamic model, the data on natural resources and resource use were fed into the GIS. No attempt was made to analyse the complex relationships between flooding, productivity and resource use. Simple comparisons between the spatial distribution of the flood characteristics (flood extent, flood duration and maximum flood level) and the spatial distribution of, for example, high quality pasture, quantities of *Sporobolus* collected and fish catches, can give some qualitative or at best semi-quantitative indications of the water needs linked to various resources. Theoretically, without a better understanding of the underlying mechanisms, these correlations cannot be extended beyond the observed flood range. However, within the observed range the resource responses appeared to be strongly flood-dependent and resource users would easily categorise the responses as either beneficial or detrimental. This allowed management to develop some relatively straightforward 'rule of thumb' predictions about the effects of certain flood types.

For example, annual and perennial grasses and sedges reacted quickly to the managed flood releases. Hydrological conditions conducive to the development of certain vegetation types could thus be identified. For livestock, the fact that sedges, which have a high fibre and a low nutrient content, replace preferred nutrient content grasses such as *Echinochloa colona*, is especially critical. Because of the varying depths in different sub-basins, such non-linear responses can be predicted by making inter-annual comparisons of the same sites under different managed flood releases. Additionally, published biological knowledge was used. For example, during the rising stage of the flood, a maximum rate of increase of water level of 1 cm per day was set. It was thought that this would allow vegetation growth to keep pace with the rising water level. The rate was based on the published maximum rate of water level increase for *"bourgou" Echinochloa stagnina* (Lecocq, 1987) and on the observation that faster rates of increase, such as those typically used by the operators of Diama dam prior to 1998, did not result in good *Sporobolus robustus* growth in the Ntiallakh basin.

For African floodplain fisheries, there is a well-established linear correlation between increasing flood extent and duration, and productivity (Laë, 1997). It was therefore expected that as the amounts of water released rose, fish catches and the numbers of piscivorous birds would increase.

4.3. Conflicting water needs

In-depth interviews with resource users were held in order to better understand traditional resource governance systems (including tenure), to sound out their resource use strategies within each basin and to record their sometimes contradictory water requirements.

On the basis of these needs, different flood scenarios were developed and their potential benefits analysed. Feedback from that analysis was discussed collectively and a compromise scenario, limited by external factors was proposed (see below). Resource users' perceptions of flood *"quality"* were assessed at the end of each season.

When stakeholders were asked about their water needs, their initial reaction would often be *"as much water as possible for as long as possible",* not surprising given the overall scarcity of water in the area. The potential impacts of the intuitive 'more is better' scenario were discussed with resource user groups. The evolution of the Diama reservoir situation, which rapidly went from a multi-user multi-purpose floodplain to an inaccessible, disease-ridden monoculture of reed-mace, served as a cautionary example. The generally more widely-travelled men were also familiar with the effects of prolonged flooding on the vegetation around the paddy fields of Keur Macène and further upstream.

Fishermen wanted an extensive flood with an early start (fish gonad size indicates that they are ready to spawn in July) and of long duration. Flood scenarios favouring fish production were also agreeable to the protected area managers, as this would increase numbers of piscivorous birds. The scenes of groups of over 1,000 white pelicans *Pelecanus onocrotalus* fishing together, a common sight during flood recession, would attract tourists (Picture 6).

The women gatherers of *Sporobolus robustus* insisted that the flood should be preceded by rain. This would have meant postponing the start of the flood release until late August most years. Such a proposal was clearly in contradiction with the needs of the fishermen (their husbands) and, prior to the first managed flood release, the two stakeholder groups were brought together and engaged in some lively discussion. The compromise proposed was to simulate rainfall by releasing a few short flood pulses in July. This would moisten the floodplain much like rain and would start the vegetative growth of the grasses. It was also agreed that, should the outcome of this test be unsatisfactory, an alternating system would be adopted, one year flooding for fish, the next for *Sporobolus robustus*. Fortunately, the results of the 'rain simulation' test were good, as it would have been difficult to force the fishermen to accept a long wait before the start of the flood release. Managing the basin for optimal *Sporobolus robustus* production would also be good for Crowned crane (*Balearica pavonina*), which use the flooded grasslands for breeding. *Sporobolus robustus* typically grows best in slightly brackish water (Van der Zon, 1992). Zooplanktivorous waterbirds such as greater flamingo (*Phoenicopterus ruber*), one of the top tourist attractions, and shoveler (*Anas clypeata*) prefer brackish water.

Livestock keepers preferred a shorter flood than the fishermen so as to obtain high quality pasture. Since the rainfed pasture on the dunes is rapidly depleted, they seek early access to the basins at flood recession. High quality pastures, especially *Echinochloa colona*, attract large numbers of herbivorous waders, such as ruff (*Philomachus pugnax*) and herbivorous ducks, such as garganey (*Anas querquedula*).

Picture 6 : White pelicans (Pelecanus onocrotalus) in the Bell basin.

Before the dam was built there had been no dry season floods (Box 3), but when these began (in 1997 and 1998) they were greatly appreciated by the livestock keepers. With water in the Bell basin channels, cattle grazing in the floodplain did not have to be taken back to the dunes in the evenings to be watered at wells. This is a very labour-intensive operation at 30 litres per cow per day. After their first experience with a dry season flood, the livestock keepers revised their water requirements to include longer water availability in the channels during the dry season.

The women did not like the dry season flood because it made access to the *Sporobolus* stands via the floodplain impossible, forcing them to walk greater distances along the embankments.

Box 3: The artificial estuary and the dry season flood release

The original purpose of Diama dam was to separate fresh water to be used for agriculture from salt water, thus eliminating the gradual fresh water-sea water transition characteristic of the estuary. An impact assessment was funded by USAID (Gannett *et al.*, 1980) but since the dam design had already been completed, only minor mitigation measures could be proposed. It was estimated that Diama would result in the loss of some 10,000 tonnes in fish and shrimp production annually and the creation of an artificial estuary was recommended.

This would also have beneficial effects on biodiversity by reducing the impact of the expected extremes in dry season salinity downstream of the dam on mangrove systems and aquatic life in general.

The Senegal delta is characterised by particularly high spring tides towards the end of the dry season, locally known as the *"Mlock"*, because of the drop in atmospheric pressure and the change in the dominant winds with the approach of the monsoon. The dam would exacerbate these by deflecting the tidal forces, which would normally dissipate up the main river channel. Through evaporation, the water in the Ntiallakh would, by that time of year (May-July), be concentrated to three times ocean salinity and, should this brine flood large areas of the lower delta, the consequences would be dire. It was therefore proposed that the Ntiallakh waters be diluted with a second managed flood release in April, the dry season flood.

Logically, the artificial estuary should have been operational before Diama dam was closed, but priority was given to investments to develop irrigated agriculture. It took another eleven years before the first dry season flood test could be performed by the park authority (cover photograph).

4.4. External constraints

External constraints included the opening and closing dates set by OMVS and the maximum water level thought to be safe for the embankments. For example, while the new embankments were under construction (1995 and 1996), flood levels were kept low to avoid damage by wave action. The embankments built by the project from compacted mud were given a very gradual slope (1m vertical for 4.5m horizontal). This facilitated the development of natural vegetation at the lower margins of the embankments. Parallel to each embankment a ditch and a levee were added (Hamerlynck & Cazottes, 1998). The stagnating water in the ditches suited the development of sedges and the accumulation of wind-blown sediment leeward of the levees led to colonisation by *Tamarix*. These measures combined afforded natural protection against wave action, gradually allowing an increase in maximum flood level (Table 3 and Pictures 24 and 25).

In contrast, the approaches to the main embankments of Diama reservoir remained practically devoid of vegetation. These embankments have a steep slope (1m vertical for 2m horizontal) and, because the hydrostatic pressure of the reservoir caused a rise in the level of the highly saline groundwater in the surrounding floodplain, the soil near the main embankment is sterile. During the rainy season, strong westerly winds dominate and when water levels are high, the main embankment can easily be damaged by waves. At flood levels exceeding 1.20 m ASL, OMVS can therefore decide to close the sluice-gates despite the fact that water is needed downstream.

The dry season flood carried with it other constraints According to the calculations made by Gannett *et al.* (1980), replacing the hypersaline waters in the Ntiallakh with fresh water would require a flow rate of 18 m^3/s. To achieve this, water levels in Bell basin would have to be high. However, unseasonal flooding would cause annual plants to germinate but would entail the risk of them not setting seed, thus leading to the depletion of the seed bank. The dry season flood pulse would have to be short, as prolonged flooding would favour colonisation of the channels by *Typha domingensis*, leading to a gradual obstruction of the flow. The park authority therefore set the maximum water level for the dry season flood release at 0.90 m ASL, confining the water transiting through Bell basin to dilute the Ntiallakh to the channels.

4.5. A consensus scenario

Using all the available information and factoring in the constraints, it was possible to design a consensus scenario to be implemented on completion of all infrastructure work (Figure 8).

Its main principles were:

- early opening of the sluice-gates (July 1st) to allow fish to enter the channels and begin spawning.
- once the plains are flooded, establish a seesaw water level pattern, gradually moistening large areas to trigger vegetative growth in *Sporobolus.*

- as from August 1st raise the level steadily at a rate not exceeding 1 cm a day until the maximum level is reached.
- maintain this level for less than 2 weeks to promote the development of high quality pasture on the higher parts of the floodplain (and recharge groundwater at the edges of the dunes).
- close the inflow sluice-gates at the end of October while maintaining the connection between the basins and the outflow to the estuary for fish and shrimp migration.
- on April 1st, begin a dry season flood release confined to the channels. Close the inflow sluice-gate on May 1st while maintaining maximum outflow for rapid emptying of the channels.

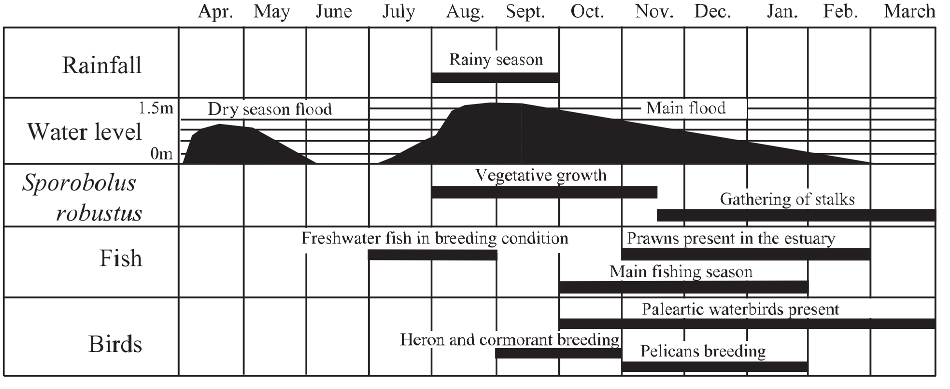


Figure 8: The consensus flood scenario and the calendar of key natural resource events for an average year.

5. The first results

In 1994 and 1995, the Lemer sluice-gate was used to test managed flood releases in the Bell basin. The response of the resources was quite spectacular, proving how resilient the ecosystems were. These small releases by the park authority coincided with much larger releases by OMVS at Diama. The latter had beneficial effects on the mangrove system and on fisheries but were too short and peaked too sharply to contribute to grassland regeneration in the Ntiallakh basin.

5.1. More of everything

With its hydraulic infrastructure completed in 1996 (see Appendix 2 for the chronology of implementation) and the consensus scenario adopted in 1997, the water in the Bell basin was now jointly managed by the stakeholders and the park authority (Hamerlynck *et al.*, 1999).

The regeneration of *Sporobolus robustus* stands meant that artisanal weaving could be resumed. In former times, the mats made from *Sporobolus robustus* by the Moorish women of the delta were famous (Picture 7).

Unfortunately, as there had been very little raw material available for over two decades, their skills had to a certain extent been lost. Only very basic mats with low added value were still being made. The project copied traditional delta mat patterns from private collections in Nouakchott, and women from Boutilimitt (where palm leaves were used for weaving similar but less durable mats) were employed to relaunch the

Picture 7: Traditional weaving of a Sporobolus robustus mat. This labor intensive activity was revived by the project and is the main source of income for Moorish women.

Picture 8: In 1997, Typha domingensis was removed by hand from the intake of the Cheyal sluice gate in order to increase flows into the Diawling basin.

Picture 9: In 1998, clearing operations were carried out by an amphibious mechanical digger.

activity. Women's groups received training on how to improve design and techniques such as the selection of uniform diameter stalks, leather tanning, the use of finer strips of leather and the production of smaller mats to cater for the developing tourist market. An indication of the importance attached to mat-weaving was observed in the Takhrédient community during the conflict over the Berbar sluice-gate. When the fishermen decided to close the sluice-gate and deny access to the park authority, the women of the community were split into two opposing camps. A fierce struggle pitted the women in favour of continued training against those who wanted to join their husbands' boycott of park activities. A few women ended up with bleeding wounds and the dispute was settled in favour of the boycott. A handful of young women from Ziré still discreetly joined the training sessions held for other communities on Birette dune.

In 1996, a low rainfall year, applying the principles of the management plan to the Bell basin, albeit at lower than optimum water levels, resulted in good fish catches and substantial plant biomass production. Numbers of both resident and transhumant livestock swelled. The lack of rainfall and the nearly non-existent flood had had devastating results all over the Senegal valley, and the basin became a magnet attracting people from a wide area. Moorish women came from up to 50 kilometres away to gather *Sporobolus* stalks. Interestingly, the local women asked the park authority to intervene because the newcomers were using scythes (instead of the local twist, turn and pull technique) and, according to the local women, this would hamper regeneration. *Sporobolus robustus* production and gathering for mat-making, which had all but died out, became a viable business. Each woman can only produce a maximum of three mats per year but the number of women gatherers increased from 20 in 1996 to 600 in 1999. Seedlings from trees such as *Acacia nilotica* also increased in numbers, but there was some initial concern about their long-term chances of survival. Seedlings tend to take root in flood marks. The flood marks of 1994 and 1995 were relatively low-lying and, as flood maximum was increasing, the seedlings would often not survive prolonged flooding in subsequent years.

In general, the local resource users adapted very quickly to the renewed abundance of resources and the economic potential this created. The pre-dam spatial distribution of resource use by each of the communities remained largely unchanged but the protected area authority, initially perceived as *"taking land for birds"*, came to be seen as the custodian of local resource use rights by an increasing proportion of the resident population.

	Bell	**Diawling**	**Ntiallakh**
1994	1.14	0.70	0.99
1995	1.16	0.55	1.07
1996	1.18	0.45	0.78
1997	1.24	0.88	1.12
1998	1.31	1.04	1.35
1999	1.49	*1.15**	*1.40**
2000	1.26	1.24	1.62

**estimates.*

Table 2: Maximum water levels in the three basins of the Lower delta in m ASL.

In 1997, the release from Diama was once again large, the Bell basin was now filled to an unprecedented level and the first, cautious test of the Cheyal sluice-gate was promising. However, OMVS soon stopped the experiment because of *"erosion"* upstream of the sluice-gate. In 1998, a very substantial amount of water was released from Diama and, with the greatly increased artificial releases into the Bell and Diawling basins (the Cheyal inflow had been cleared: Pictures 8 and 9), more than 25,000 ha were flooded. Catches of freshwater fish shot up to 400 kg/day in 1997 and to 1000 kg/day in 1998 (Table 2 and 3). In the estuary, large numbers of shrimp *Penaeus notialis* attracted a businessman who brought cold storage, nets and … fifty foreign fishermen. The Takhrédient, who called on the park authority for support (and wanted *"Diawling National Park resident"* badges to distinguish themselves from the newcomers) were quick to assert their precedence and rebuff the outsiders.

With the return of the floods, warthog (*Phacochoerus africanus*) populations in the park had increased tremendously and started dispersing into neighbouring areas. The hunting lodge in Keur Macène, which had been closed for over ten years, was reopened by a private entrepreneur. Senegalese tour operators brought truckloads of tourists over the border. However, neither local communities nor the park authority benefited from this since the tourists were able to see most of the birds from the embankments and dunes without actually entering the park. The park's delimitation which, as the result of a compromise, was restricted mainly to the floodplain and did not include any road infrastructure or human settlement, now proved to be a disadvantage.

	Bell	**Diawling**	**Ntiallakh**	**Total**	**Fish catches (Lower Delta)**	**Waterbirds (Lower Delta)**
1992					< 1 000	2 216
1993					< 1 000	5 292
1994	3 210	5 110	6 700	15 020	*10 000**	66 100
1995	3 320	3 850	9 070	16 240	*15 000**	32 300
1996	3 430	3 140	3 530	10 100	10 800	14 400
1997	3 720	6 710	9 890	20 320	25 500	40 900
1998	4 000	10 160	12 890	27 050	74 500	35 098
1999	4 370	12 050	13 470	29 890	113 800	38 413
2000	3 810	13 860	14 720	32 390	*no data*	*no data*

** estimates from daily catches, as reported by the fishermen.*

Table 3: Flooded surface area in the lower delta basins (in ha), total flood season fish catches at Lemer and Cheyal sluice-gates (in kg) and number of waterbirds counted during the International Midwinter Waterfowl Census (in mid-January of the subsequent year).

In ecological terms things were going very well, but the rapid developments placed a strain on the park as an institution, and this was compounded by high turnover of key staff. Moreover, the park was being challenged on the political front by the rice-farming lobby and by proponents of a dam on the Ntiallakh (Box 4).

Box 4: The Ntiallakh Basin controversy: artificial estuary or freshwater lake?

In the early 1990s, with Diama reservoir established, private investors swarmed into the Ndiader basin around Keur Macène. They succeeded in obtaining agricultural concessions on about 80% of the irrigable land. They had little difficulty in obtaining loans for equipment and agricultural inputs, and initial yields were quite satisfactory. However, the equipment in most of the fields was very basic and the soils quickly became saline due to poor drainage. By 1997, only 15% of the irrigated land was being farmed and the average yield had dropped to 1.1 tonnes/ ha/ year (JICA *et al.*, 1997).

In Diawling National Park's early days, belief in the potential of irrigation was still high and many people in the lower delta thought they should also benefit from it. The Takhrédient fishermen took exception to this and said they would take up arms against anyone who tried to lay claim to their fishing grounds with a view to converting them to farming land. The 1987 land use plan (Gersar, 1987) had identified only 400 ha of land in the lower delta which would be marginally suitable for irrigation, but other studies suggested establishing 20,000 ha of paddy rice farms in the lower delta by building a series of dams and sluice-gates in the Ntiallakh basin. More detailed investigations led to the conclusion expressed in the 1993 (BDPA, 1993) land use plan, that nowhere in the lower delta, neither in Diawling National Park nor the Ntiallakh basin, did the soil show any agricultural potential due to its high salinity.

And yet, the communities of the coastal dune continued to believe that a dam on the Ntiallakh would solve all their problems: the vast freshwater lake would provide them with drinking water, the embankments would become access roads and the flooded areas could be cultivated. Obviously, such a dam would have meant the end of the artificial estuary and would have nullified efforts to rehabilitate the mangrove ecosystem. The National Park therefore opposed it.

By 1997, most of the private investors in the Ndiader basin had defaulted on loan repayments and abandoned the sterile fields. Demand for the allocation of new irrigable land increased considerably. The agricultural lobby pressurised the government to degazette 8,000 ha in Diawling National Park and convert it to irrigated agriculture. The construction of a dam across the Ntiallakh was once again on the agenda. After an extremely damning cost-benefit analysis and strong protests from the wider donor community, the whole project was finally jettisoned in August 1998. New irrigable land will have to be found east of Rosso, in areas of traditional flood recession agriculture. The lobbyists are now targeting an eastward extension of the Diama embankment and a further increase in the reservoir's water level. If successful, both of these changes are likely to exacerbate the negative environmental, health and socio-economic impacts of Diama reservoir.

5.2. Turning the tide: the artificial estuary

The first dry season flood was tested in April, 1997 (Box 3 and cover photograph). Keeping the water in the channels while achieving the maximum flushing effect on the Ntiallakh required subtle fine-tuning of inflow at Lemer and outflow at Bell. As OMVS was the only authority allowed to operate the sluice-gates, close cooperation was essential, especially since previous experience had shown that the system was far from flexible. In principle, the management plan had been officially approved and therefore the dates for sluice-gate openings and closings had been set. Nonetheless, any intervention still required the approval of a long chain of decision-makers and actors. The Director of the National Park would write to the Director of Sonader (the national focal point of OMVS) who would notify his Trarza province representative in Rosso, who would in turn notify the OMVS office in Rosso, who would send a radio message to the dam operators at Diama, and the people holding the keys to the Cheyal, Lemer and Bell sluice-gates. On average, sluice-gates were opened three weeks later than requested. Obtaining timely adjustments of sluice-gate apertures required considerable diplomatic skill and perseverance or, alternatively, a bit of nocturnal stealth and audacity.

In the first test, the Lemer sluice-gate was opened and a small inflow reached the Ntiallakh and brought down the salinity in its northern half (Figure 9). As Bell 2 sluice-gate was not yet fully operational, the low flows recorded were not entirely

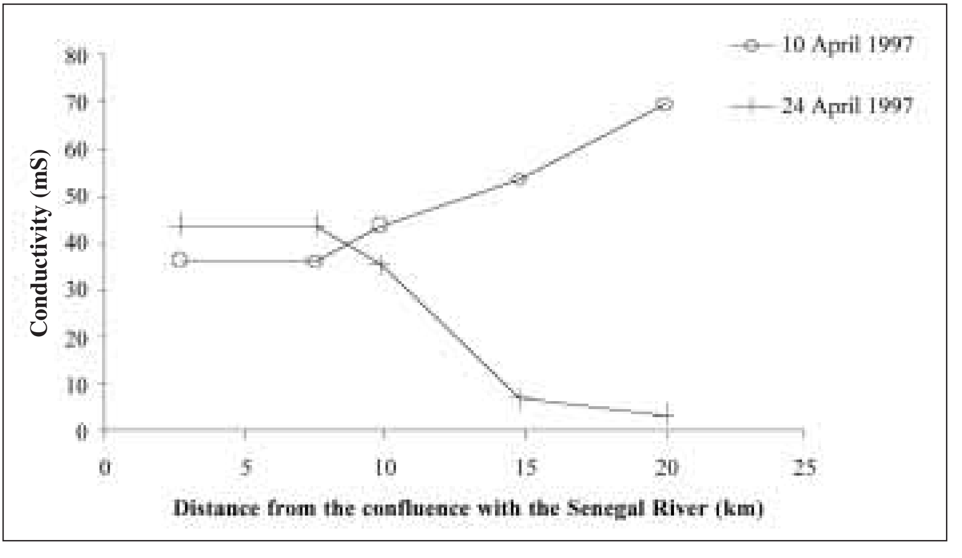


Figure 9: Salinity in the Ntiallakh basin: on April 10th 1997, the salinity profile showed a typical "inverse" estuary profile with salinity increasing towards the northern end of the Ntiallakh, furthest from the connection with the Senegal River and sea water. Two weeks later, when the dry season flood release peaked, the salinity profile was typically estuarine and, at the northern end, had dropped from 69,5 milliSiemens to 3,5 milliSiemens (53 g/l to 2.6 g/l).

unexpected. In 1998, however, the thresholds at the sluice-gate had been removed and the flow rate still remained low. In fact, vast quantities of windborne sediment had filled a several kilometre-long stretch of the Bell channel, the connecting link between the Bell basin and the estuary of the Ntiallakh. Moreover, this threshold prevented proper drainage in the channels; this in turn led to *Typha* growth which further reduced flows. After the 1998 dry season flood, the stagnant waters in the Bell basin were partially drained into the Diawling through the Berbar sluice-gate. Despite this, *Typha* continued to encroach on the channels. Therefore, no dry season flood release was carried out through the Bell basin in 1999. An attempt was made to dilute the Ntiallakh waters through the Diawling basin but, due to OMVS repairs to the Diama embankment, the flow rate was too low and the release period too short for the water to reach Lekser. Still, the experiment created favourable feeding conditions for the lesser flamingo (*Phoeniconaias minor*) in May and June. This may have contributed to its putative first successful breeding attempt in West Africa since the 1960s (Hamerlynck & Messaoud, 2000).

5.3. On the (drinking) water front

In 1996, the park had the situation well in hand: the first phase of infrastructure works had been completed, the ecosystems were functioning, constructive relationships had been established with an increasing number of stakeholders, a very promising partnership was developing with the Groupe de Recherche sur les

Picture 10: Mangrove regeneration. Increased salinity in the Ntiallakh basin during the 1990s all but destroyed the mature mangrove stands. With the return of the floods, propagules from the few surviving trees quickly recolonised the area.

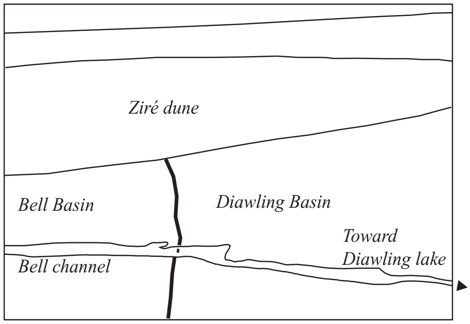
Zones Humides (GREZOH) at the Nouakchott University Faculty of Sciences and its high level decision maker support was boosted through the activities linked to the Integrated Coastal Zone Management Plan for Mauritania (PALM). More importantly, funding had been secured from the Agence Française de Développement (AFD) for the *"orphans"* of the management plan: the drinking water supply and road access programmes. AFD would also further develop some of the starter activities, such as horticulture, and support the marketing side of the sustainable use activities. A third donor, the Fonds Français pour l'Environnement Mondial (FFEM=French GEF) was stepping in to bolster the research effort into the links between water and environmental and economic values, to enhance the park staff's capacity and to develop a zoning plan for the proposed Biosphere Reserve.

However, things were not to be so straightforward. The new donors also had their own procedures and the chain of command for expenditure approval was not going through IUCN. In fact, in the 1996-1999 phase, IUCN would primarily provide technical assistance and test a few more starter activities, such as boat building and ecotourism. A gentleman's agreement to that effect existed between IUCN and the French donors but it did not appear in any of the official documents sealing the bilateral agreement between France and Mauritania. Similarly, in the contract between IUCN and the Mauritanian government, no procedures which might have existed between IUCN and the French donors were mentioned. Since the different agreements were not signed at the same time, co-ordination problems arose. Working with several donors through separate bilateral agreements proved to be less flexible and slowed down the implementation of activities, such as the provision of drinking water.

Picture 11: *Aerial view of Diama dam in December 1994 (view from the south east): in the foreground, Diama impoundment; in the background, downstream from the dam, Birette dune.*

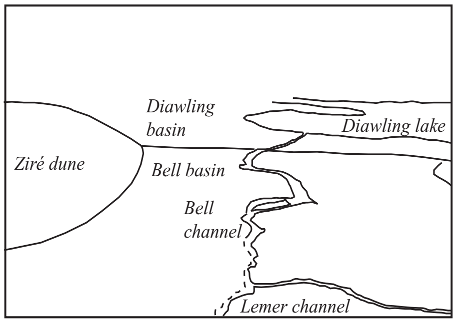
Picture 12: *Aerial view of Diama dam in January 2003 (view from the northeast): in the foreground, Diama impoundment colonised by Typha domingensis; in the background, downstream from the dam, the estuary of the Ntiallakh and its former mouth at Boytet, now separated from the Atlantic Ocean by a coastal dune.*

Before: December 1993



Picture 13: *In December 1993, the northern part of Bell basin and the southern part of Diawling basin were virtually without vegetation cover, except for some salt-resistant Chaenopodiacea, a few Tamarix along the former water courses, and some patches of grasses or sedges around rainfed depressions.*

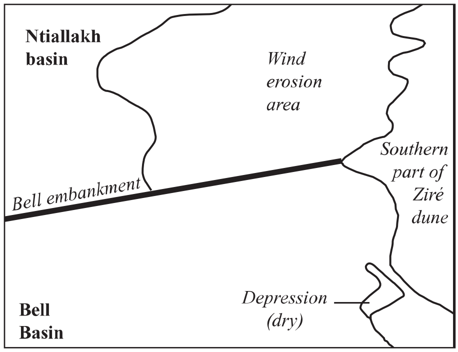
After: October 1998



Picture 14: *In 1998, the flood covered most of the basins and aquatic vegetation was developing. After the flood had receded the lower-lying terraces were covered with annual grasses, providing excellent grazing for domestic animals and favourable conditions for warthogs. The lower lying areas were covered by sedges.*

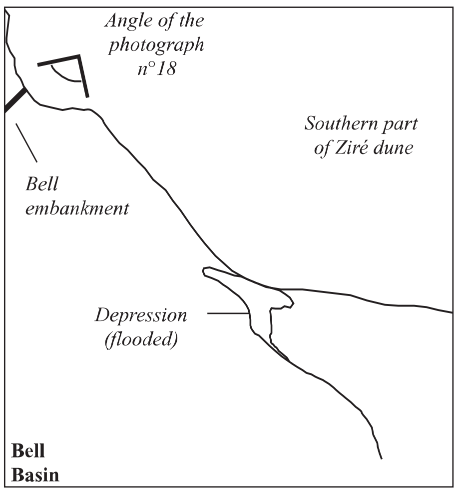
Picture 15: *In 1998, thousands of ruff (Philomachus pugnax), Bar-tailed godwits (Limosa limosa) and other waterbirds used the grasslands in Bell basin during flood recession. The Acacia nilotica tree on the right died when the basin remained unflooded after the Diama reservoir embankment was built.*

Before: December 1993



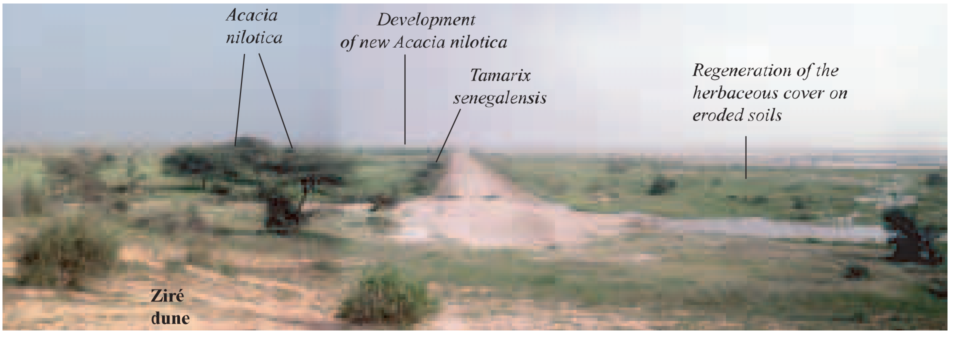
Picture 16: *In December 1993, after several years without flooding, there was no growth of annuals and perennial vegetation was in decline. The saline soils of the floodplains lost cohesion and became very sensitive to wind erosion.*

After: October 1998



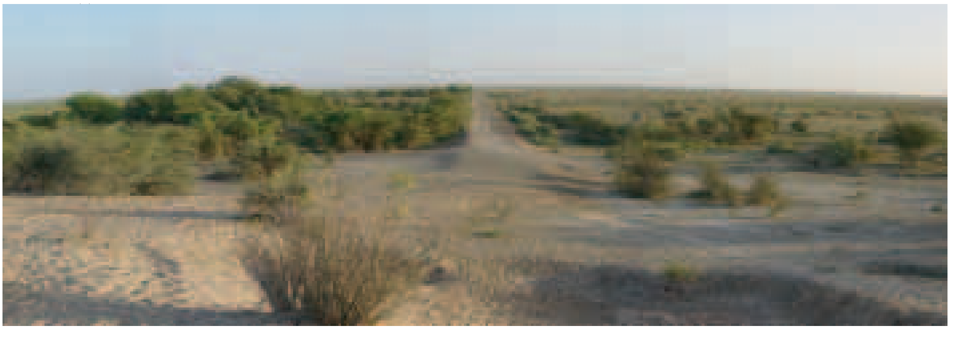
Picture 17: *Since the return of the floods in 1994, vegetation has returned and the regeneration of Acacia nilotica woodland has begun.*

Before: October 1998



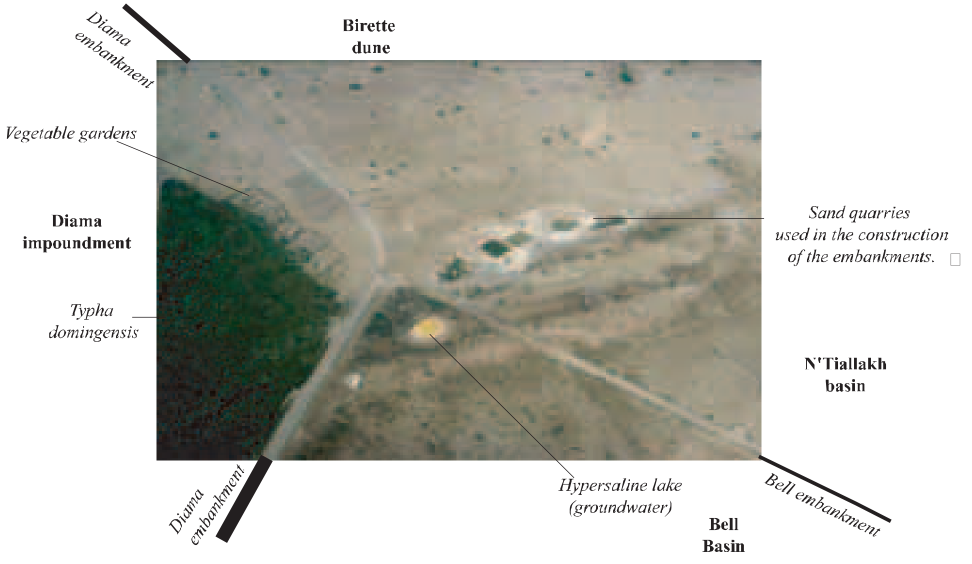
Picture 18: *In October 1998, after four years of flooding, the older Acacia nilotica are healthy and producing seeds, young trees from these seeds colonise the floodmarks along the water courses. Tamarix senegalensis protect the embankments from wave action. Annual and perennial grasses provide grazing and reduce erosion.*

After: January 2003



Picture 19: *A small grove of Acacia nilotica has grown up at the foot of the dune. The species has also begun to colonise Ntiallakh basin.*

Before: December 1993



Picture 20: *In December 1993, a sharp contrast can be observed between the permanently flooded Diama impoundment and Bell and Ntiallakh basins, where only a few scattered Tamarix survive. Hydrostatic pressure from the impoundment raises the level of the saline groundwater, which (through evaporation) becomes highly concentrated.*

After: October 1998

Picture 21: *In October 1998, the water level in the impoundment has risen. Renewed flooding in Bell basin allows development of Tamarix senegalensis, the hypersaline lake is being diluted and the area has become attractive to waterbirds. An exclosure on Birette dune, dating from 1996, has allowed Acacia tortilis to regenerate into a dense stand. The flood release from Diama has filled the entire Ntiallakh basin and reaches the western side of Bell embankment.*

Before: October 1998

Picture 22: *The same site as in picture 21 seen from ground level; Acacia tortilis has begun to recolonise the exclosure.*

After: January 2003

Picture 23: *Four years later, the exclosure has evolved into a dense Acacia tortilis forest.*

Before: October 1998

Picture 24: *A view ok Lekser dike from Ziré dune, looking west toward the coastal dune. A series of ridges and trenches create wind breaks and accumulate water, thus creating favourable conditions for Tamarix senegalensis.*

After: January 2003

Picture 25: *Several years later, Tamarix senegalensis is well-established and provides effective protection against wave action. However, if the Prosopis juliflora bushes in the foreground are not removed, their roots may damage the dike.*

Before: December 1993

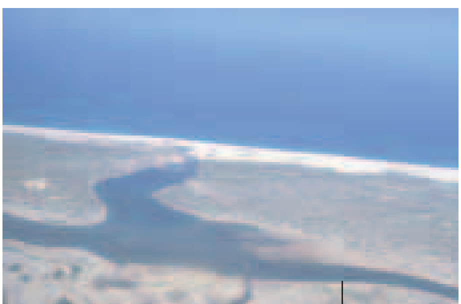
View from the east

View from the west

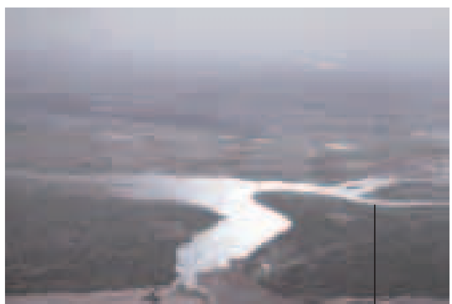
Pictures 26 & 27: *In December 1993, Chat Tboul was an extremely hypersaline lagoon (over 100g/l). In the view from the west, sand dunes have transgressed beyond the former shoreline (marked by a row of Tamarix senegalensis) and have separated the main lagoon from "Mullet Lake" which, through seepage of fresh water from the dunes, has a salinity of "only" about 50g/l, meaning mullet can survive there.*

After: October 1998

View from the east



View from the west



Pictures 28 & 29: *The managed flood releases into the Diawling Basin have reached Chat Tboul and even filled the southern depressions of Aftout es Saheli. Thousands of cormorants, white pelicans, greater and lesser flamingos and many other waterbirds have returned to the area.*

6. Analysis

6.1. Achievements

Between 1991 (the year Diawling National Park was established) and 1996, hydraulic infrastructure and management procedures were put in place, allowing managed releases of water to fill the depressions, inundate the floodplains and create a salinity gradient in the Ntiallakh estuary.

Ecological monitoring and management capacity has been acquired by local staff and functional partnerships have been established with research organisations in Mauritania and abroad, as exemplified by the development of the hydraulic model for the park's basins. These partnerships are gradually filling the gaps in our understanding of the water needs of the various ecosystem components. They also provide backstopping when observed changes in the functioning of the restored ecosystems call for management adaptations.

Picture 30: Women gathering Acacia nilotica seedpods to be used for tanning leather. Although some adult trees have survived, seedpod production plummeted when the floods ceased. Under managed flood releases, seedpod production resumed and young trees have colonised the higher parts of the floodplain.

Through the implementation of its management plan, Diawling National Park has succeeded in rehabilitating a substantial portion of the lower delta, both inside and outside of the protected area (Picture 13 to 29). Ten years on, what could only be described as a salt desert in 1991, is once again a thriving complex of interconnected ecosystems. Plant diversity, vegetation cover and pasture quality have increased, allowing a revival of livestock keeping (especially cattle), a livelihood which was traditionally the preserve of the marabouțic tribes (Tandgha). Artisanal mat weaving by the local women using *Sporobolus robustus*, a brackish water-dependent perennial grass, is flourishing again. The characteristic *Acacia nilotica* woodland of the floodplain is making a comeback. This in turn has led to the renewal of the traditional leather tanning activities which require *Acacia* seedpods (Picture 30). The few mangrove stands that survived the drought and hypersaline conditions exacerbated by Diama dam are now healthy and produce large quantities of seedlings which are successfully recolonising the estuary (Picture 10). The nursery function for estuarine and marine fish and shellfish has been restored, and freshwater fish catches have increased concomitantly with the expansion of the flooded area (Table 3). Migratory (Table 3) and nesting (Table 4) waterbirds have returned in numbers that often more than satisfy the criteria for inclusion in the List of Wetlands of International Importance under the Convention on Wetlands (Ramsar, Iran, 1971), thus creating considerable potential for ecotourism.

Scientific name	Common name	Nesting pairs in 1993	Nesting pairs in 1999
Pelecanus onocrotalus	White Pelican	0	1400
Pelecanus rufescens	Pink-backed Pelican	0	5 to 10
Phalacrocorax lucidus	White-breasted Cormorant	< 30	> 500
Phalacrocorax africanus	Long-tailed Cormorant	< 50	> 250
Anhinga rufa	African Darter	0	> 25
Nycticorax nycticorax	Black-crowned Night Heron	<5	> 100
Ardeola ralloides	Squacco Heron	< 50	> 150
Bubulcus ibis	Cattle Egret	< 10	> 250
Butorides striatus	Green-backed Heron	<5	> 10
Casmerodius albus	Great Egret	0	> 200
Egretta garzetta	Little Egret	< 25	> 200
Egretta gularis	Reef Heron	0	>5
Platalea alba	African Spoonbill	0	5
Alopochen aegyptiaca	Egyptian Goose	0	> 5
Gelochelidon nilotica	Gull-billed Tern	0	> 100
Larus cirrocephalus	Grey-headed Gull	0	> 10
Balearica pavonina	Crowned Crane	2	> 30

Table 4: Nesting bird populations in the lower delta at the start of the project and in 1999.

Although it has not been formally quantified, the economic upswing linked to the restoration of the area's natural resources is thought to have been instrumental in improving the livelihoods of women and men alike. The exodus of the young and able-bodied has been stemmed in some communities, creating an enriched social environment. The local communities' fears of exclusion from natural resource use have proved unfounded and the initial hostility towards the protected area has dissipated, opening up the possibility of expanding it to encompass important habitats (forested dunes, mangroves, estuarine mudflats, the seashore and coastal zone) not currently represented in the National Park.

Through its awareness-raising efforts, Diawling National Park has gained recognition at different levels within Mauritania and abroad, especially for its successful integration of conservation and development. The constituency thus built has capably dealt with major threats such an impoundment in the Ntiallakh estuary and the conversion of thousands of hectares of floodplain for irrigated rice growing – a type of agriculture that has been proven to be ecologically unsustainable and economically non-viable.

The lively activity around Diawling National Park during its first decade of existence has strongly stimulated the process aimed at establishing an Integrated Coastal Zone Management Plan for Mauritania. Dynamic networking by the park has influenced the designation of a Ramsar site at its northern limit around Chat Tboul lagoon, and interactions with Banc d'Arguin National Park are constructive. The creation of a cross-border Biosphere Reserve, which would incorporate all the lower delta wetlands, both Mauritanian and Senegalese, is at present on the agenda. Other positive spin-offs are the establishment of a M.Sc. course in water and wetland management at the University of Mauritania at Nouakchott; various wetland management, conservation and rehabilitation projects in other wetland areas (lake Aleg and lake Mal, the Tamourts of central and eastern Mauritania); the planned restoration of the nursery function for marine fish and shrimp at the Ndiael Ramsar site in Senegal (Figure 1) by reconnecting the depression with the river downstream from Diama dam, etc.

Initially funded entirely by the Government of the Netherlands, Diawling National Park has diversified its donor support base. At national level, the Diawling example has raised awareness about environmental issues and the linkages between environment and development, thanks in part to the high advocacy profile of Nouakchott University's Wetlands Research Group (GREZOH). Institutional capacity on wetland management issues has benefited from the existence of the Diawling project.

6.2. Outstanding issues

Managing human resources is a delicate undertaking anywhere in the world. In a situation where assessments of staff performance are at least partially based on personal relationships, it is often difficult to retain the most competent members of staff. This means that those who have benefited from the park's considerable investment in capacity building have not always remained on the staff. Furthermore, ensuring that information circulates smoothly has proved to be a challenge in logistical terms and also because of hierarchy and the hope that accumulating information individually will lead to professional advancement. Rapid turnover of key personnel, poor management of human resources in general and impediments to information flows have affected the continuity of vital ecosystem and socio-economic indicator monitoring. Even in such difficult conditions, continued team-building efforts are essential if the park's achievements are to be consolidated.

One of the stated objectives of the officially approved management plan was to carry out field activities, but no specific government budget has ever been allocated for these activities which have thus remained totally dependent on donor funding. Without a budget allocation, the Chief Warden and his staff cannot react quickly to meet urgent needs such as embankment protection during a flood, building repairs after a rainstorm or minor repairs to vehicles, etc. The final costs thus tend to be substantially higher than they might have been if immediate action had been taken. Also, with no allocated budget, field staff cannot decide to spend a few days at sites where there are interesting hydrological or biological phenomena to be monitored, or step up surveillance at breeding sites, etc. Setting aside a part of the visitors'entry fees, to be added to the operational budget, could be a solution. For this to be effective, the park's boundaries would have to be redrawn, since tourists can now view most of the interesting sites without paying to enter the protected area.

The establishment of a Scientific and Technical Research Committee to advise on the complex technical issues involved in managing a protected area was perceived as a top priority in 1993. Unfortunately, Diawling National Park did not act to set up the committee until 2001. Social scientists are presently under-represented among its members, but it is hoped that the committee will gradually build up its expertise as it establishes its workplan. Given the threat of irreversible changes to the ecosystem, most notably the rise of saline groundwater levels, the monitoring and research programmes will need to be revived and strengthened.

The long delays in implementing the more specifically rural development components of the programme (water supply, road access) create a risk that the communities will become disenchanted. The reasons for these delays are often difficult to explain to the local people, and rumours will obviously compete for the public's attention. One of those rumours has never really gone away, namely that the park is only there for the birds and that the hidden agenda is to make the lower delta inhospitable for human communities, forcing them to emigrate. Only continued open and honest communication between the park administration and all segments of delta societies, joint efforts to provide the donor community with reliable information, and addressing governance issues in the institutions involved in implementation, will resolve this.

Several factors continue to hamper interaction between OMVS and the protected area managers: communication difficulties with relevant OMVS bodies, difficult access to OMVS-held data, the organisation's sectoral foundations and its limited familiarity with concepts such as local non–agricultural stakeholders, water for the environment, ecosystem-based management, etc. On a wider scale, there is a bigger danger stemming from the fact that the management of the river basin as a whole is far removed from ecosystem-based management. This has led to serious deterioration in the status of natural resources and livelihoods elsewhere in the valley which may increase the pressure on the restored ecosystems beyond sustainable levels (*i.e.* if a drought occurs in two consecutive years), and may furthermore lead to much more serious social unrest than the 1989 conflict. The establishment of an environmental observatory for the Senegal River basin (in May, 2000) may be a constructive first step towards a solution. The fact that the observatory is part of OMVS, and not a decentralised independent multi-actor forum for the exchange of information, casts some doubt on how effective it will be. The park should try to build a good working relationship with this new entity, both by supporting it through the input of data and by using its outputs (e.g. satellite images at flood peak to be used in model validation). Hopefully, the observatory's terms of reference will be expanded to include socio-economic indicators.

Picture 31: Salvinia molesta, an invasive aquatic fern, was accidentally released into Diama reservoir during the 1999 flood. The dense floating mats it forms hindered the park's managed flood releases in 2000.

Based on past experience, some doubt remains as to OMVS's technical ability to cope with extreme situations such as an exceptionally heavy flood. The lower delta embankments are fragile structures that can easily be swept away by inappropriate operations. Continued communication with OMVS at all levels and increased contact with the wider *"dams and development"* community could help to expand the organisation's mind-set and improve its performance.

Several technical issues still need to be resolved. For example, the water levels in the Bell basin remain too high for too long after the floods. This leaves the door open to invasive aquatic plants. All fishermen would have to agree to leave the sluice-gates at Bell and Berbar partially open at flood recession and the Bell channel would have to be cleared of windborne deposits. The whole dry season flooding procedure also warrants continued attention. Should it prove impossible to obtain managed releases from Diama in March-April, the possibility of adding a sluice-gate at the northern tip of Birette dune should be explored. This will provide for direct dilution of the hypersaline waters in the Ntiallakh basin without the need for water to transit through the Bell basin.

The hydraulic models need to be validated, refined and continuously updated with new information from the monitoring system. Simulations should be conducted for engineering operations such as lowering or raising the thresholds between depressions within a basin; widening or deepening certain watercourses; installing additional sluice-gates (in order to analyse management advantages); exploring alternative methods of diluting the Ntiallakh; fine-tuning the timing and magnitude of managed releases, especially in conjunction with releases from Diama dam. The impacts of the expected changes in flood regime downstream of Diama now that hydropower production is becoming a major water user, also need to be examined.

6.3. Threats

As in most countries, one of the main issues is how the benefits derived from natural resources should be shared. The local communities have few opportunities to invest in technology that could increase the added value of their products. Similarly, marketing practices are generally monopolistic and, due to a tradition of strict separation of socio-economic roles between producers and traders, the producers have virtually no access to marketing channels. They therefore tend to get less than a fair share of the profits. Resolving the equity issues may be a long process with small incremental successes and occasional setbacks. Facilitating access to emancipatory tools may be helpful.

The attractiveness of the restored part of the delta, which contrasts starkly with the continued environmental degradation of large areas of the Senegal valley, could lead to an influx of *"ecological refugees"*. This could result in unsustainable levels of resource use. Again, OMVS is the key organisation with whom this issue must be addressed. Supporting OMVS and its member countries in the difficult transition from a sectoral to a basinwide ecosystem approach is one possible strategy. This could be supplemented by the rehabilitation of failed rice schemes based on the lessons learned in the lower delta.

7. Ecosystem management

The principles of the ecosystem approach were developed by the Subsidiary Body on Scientific, Technical and Technological Advice of the Convention on Biological Diversity (CBD) at its fifth meeting (Montreal, January-February, 2000). They are based on the *"Malawi principles"* drawn up at a workshop sponsored by Malawi and the Netherlands, which took place at Lilongwe in January, 1998.

The ecosystem approach is an integrated approach to the management of land, water and living resources which promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies focused on levels of biological organisation which encompass the essential processes, functions and interactions among organisms and their environment. It recognises that human beings, along with their cultural diversity, are an integral component of ecosystems. The focus of the ecosystem approach on processes, functions and interactions is consistent with the definition of an ecosystem as a dynamic complex of plant, animal and microorganism communities and their non-living environment, interacting as a functional unit. The ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the lack of complete knowledge or understanding of how they function. The purpose of this section is to assess how the project has applied the 12 principles adopted by the CBD (Annex 1).

The general approach of the Diawling project, i.e. beginning with a multidisciplinary team and including many follow-up field visits to get a detailed picture of pre- and post-dam natural resource use by local communities and to analyse their perception of ecosystem functioning, was from the outset different from the more conventional protected area or species conservation approaches. It was reasoned that if the ecosystems could be made to function again, this would be beneficial for both the resources and the communities which depend on them. The restoration of biodiversity values would be a kind of by-product, in other words it would provide proof that functions had effectively been restored.

After each managed flood release, there was intense interaction with the local stakeholders about the perceived links between the flooding and the vegetation available for grazing and gathering, and on the effects of the flood on fish production. These subjective assessments were supplemented by monitoring data on water, vegetation, fish catches, livestock and wildlife, especially waterbirds.

These findings were the key input to the planning of the flood regime for the next season. Thus, for example, based on the recollections of the older inhabitants of Ziré Takhrédient, the decision was taken to increase maximum water levels in the Bell basin from 1.10 m ASL to 1.40 m ASL which, as it became clear retrospectively, matched their visual memory of the perfect flood. In practice, the level was increased gradually from 1994 (1.10 m ASL) to 1999 (1.40 m ASl), both to evaluate how the newly built hydraulic equipment would withstand it and to see how the ecosystem would react. Gradually, larger areas were flooded, creating high quality grazing areas on higher ground, allowing trees at the edges of the dunes to regenerate and at the same time increasing fish production.

Conversely, it was felt that the duration of the floods should be shortened to avoid colonisation by sedges (*Bolboschoenus maritimus*) and reed-mace (*Typha domingensis*), and that the basins should be completely dry for considerable lengths of time. Unfortunately, progress toward this objective was hampered by the wind-deposited thresholds which had developed downstream of the Bell sluice-gate, obstructing outflow from the Bell basin towards the Ntiallakh. Similarly, the dry season flooding of the Bell basin was avoided both in 1999 (by trying to achieve it through the Diawling basin) and in 2000 (unnecessarily, because of the prolonged releases from Diama dam which kept salinity downstream at acceptable levels throughout the dry season).

The flood/stakeholder feedback process also made it possible to formulate hypotheses about the hydrological requirements of *Sporobolus*, a species which is vitally important to the local economy; the women of Birette, whose prime *Sporobolus* gathering areas are outside the park and under the direct influence of the releases from Diama dam (which can be compared with the managed floods within the park's basins) played a particularly important role in this process. Alhough some years saw substantial flood releases by Diama, water level increases were usually too abrupt to allow the vegetation to develop at its normal rate. The more gradual incremental rises in the park's basins resulted in much more productive *Sporobolus* stands.

These are but a few examples to illustrate the fact that the whole exercise followed a *"hands on"* approach. Project staff, park managers and stakeholders were all involved and, where resources were available, the approach was supported by scientific investigations. One can only hope that these results will be taken into account when, in the hopefully not too distant future, the management of Diama dam and of the river basin as a whole becomes ecosystem-based.

7.1. The 12 principles

1. **The objectives of management of land, water and living resources are a matter of societal choice.**

The rationale given by the CBD for this principle emphasises the role of the local stakeholders. The cultural diversity, traditional rights and needs of various local user groups were taken into consideration in implementing the project. Local livelihoods in the project area, being virtually totally dependent on ecosystem productivity, were largely compatible with the biodiversity targets set by the international community. Still, society is a complex and diverse entity in which choices and information flows are often impeded by vested interests, governance issues, etc. In this instance, a number of hurdles were encountered at intermediate levels of society and these may have been exacerbated by the avant-garde nature of the approach.

2. Management should be decentralised to the lowest appropriate level.

The appropriate level, and also initially the only possible way to work was to deal directly with the natural resource users and their traditional, informal organisations (twize, jeema, clan or tribe). The municipal council, the lowest formally elected institutional level was initially hostile to the project's approach. The council was a strong proponent of a dam on the planned artificial estuary with a view to developing 20,000 ha of irrigated rice on highly saline soil (Box 4). However, once the benefits of the ecosystem restoration approach filtered through to the municipal council from the traditional user organisations, collaboration became possible. In general, many of the barriers to decentralisation are similar to those listed under principle 1.

Picture 32: Takhrédient fishermen were among the first supporters of the managed flood releases.

3. Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

The project's purpose, strictly speaking, was to establish Diawling National Park (16,000 ha), but the management plan explicitly included any area that could be affected by the flood releases (some 50,000 ha in the lower delta and the contiguous coastal lagoons to the north) as well as the adjacent drylands.

However, the lack of an ecosystem management approach in the valley as a whole and the consequent failure to consider effects downstream of the dams has been one of the major causes of environmental and social disruption. More specifically, in the lower delta, the entire Diawling restoration operation was the indirect result of the perception that recommendations made by the Diama dam environmental impact assessment were not a high priority in comparison with the infrastructure needed for irrigated agriculture, and were therefore not implemented. As long as highly centralised sectoral management prevails, this approach remains a threat to the valley's ecosystems. It also means that the outside pressures on the relatively small restored area could easily be exacerbated. There is an opportunity here to apply the ecosystem approach to restoring areas where irrigated agriculture has been attempted. If successful, this model could be applied, with local adjustments here and there, to the entire river valley.

4. Recognising potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:

a) Reduce those market distortions that adversely affect biological diversity;
b) Align incentives to promote biodiversity conservation and sustainable use;
c) Internalise costs and benefits in the given ecosystem to the extent feasible.

The principle is a sound one, but the project did not have the expertise to apply it fully. Building hydraulic infrastructure for an artificial wetland is a costly undertaking, and the recurring costs of operation and maintenance are considerable. A high priority should be given to evaluating to what degree the maintenance costs of the hydraulic equipment can be internalised (e.g. through access fees for fisherfolk, gatherers, livestock keepers, ecotourism development, etc.). Given the economic and social crisis at the time the project was launched, it would have been very difficult to charge residents simply for using their communal lands (now 'privatised' for conservation) as they had always done.

Under the joint management agreement, local users can keep their resource use rights in exchange for their contributions (through their local knowledge) to the development of the management plan and their assistance in policing. Local tenure systems preclude individual land ownership but guarantee land use rights to clans, tribes and other traditional organisations. Moreover, in a country with highly nomadic traditions, distinguishing between *"local users"* and *"outsiders"* might prove rather tricky with respect to livestock keepers. Logically, most of the recurring maintenance and monitoring costs should be borne by OMVS as the entity responsible for the disruption of ecosystems and livelihoods. In practice, because most of the organisation's activities fail to generate a surplus, OMVS lacks the necessary budget to apply corrective or compensatory measures. Despite the current shift in favour of maintaining an artificial flood regime in the valley, it is not unlikely that the organisation's spending priorities will continue to be geared towards achieving its primary objectives. Increasing OMVS's awareness of and gaining its commitment to an ecosystem approach should be foreseen as a long and difficult process. At national level, the nursery function for shrimp, mullet and other exploited marine species could justify central government support (e.g. through taxes levied on fish product exports) for infrastructure maintenance.

From a broader perspective, had this principle been applied to the valley prior to the construction of the dams, had the true costs of the conversion to irrigated agriculture been internalised (using reliable productivity hypotheses, etc.), and had there been no economic crisis in the North favouring less stringent evaluation of lending for large infrastructure projects whose cost-effectiveness was doubtful, it is unlikely that the dams would ever have been built. At the very least, the sectoral approach of OMVS might have been deemed unacceptable. Economic valuation of the traditional floodplain uses might also have led to the conclusion that an integrated or ecosystem-based approach with emphasis on strengthening traditional uses, and a much more gradual, bottom-up introduction of irrigated agriculture, was a viable alternative.

5. Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

The whole management plan was built around ecosystem functions, with the expectation that biodiversity would return under favourable conditions. This hypothesis proved correct, but it should be emphasised that Sahelian estuarine ecosystems have only a small number of restricted-range, highly specialised endemic species. In general, due to a high degree of variability, Sahelian floodplain and deltaic ecosystems are characterised by opportunistic and highly adaptable species. In this case, therefore, productivity (functional aspect) and biodiversity (structural aspect) are not mutually exclusive.

6. Ecosystems must be managed within the limits of their functioning.

The cautious approach of the project, which entailed gradually increasing the level and duration of the artificial flood while observing ecosystem response, was the appropriate way forward. However, in a society where water is in very short supply (Sahel droughts of 1972-73 and 1982-83) there is an understandable tendency to think that *"more is better"*. At flood recession, when Diawling National Park's basins should have been emptied, there were covert closures of the outflow sluice-gates in one of the park's basins, allowing local fishermen to harvest fish that would otherwise have migrated to downstream areas. This retention of fish, and fresh water, encouraged the establishment of invasive weeds, encroachment by sedges on good pasture land and resulted in insufficient die-off of vegetation during the dry season to allow for effective nutrient recycling. It also increased the risk of parasitic diseases in humans and livestock. It is unfortunate that the project failed to convince all stakeholders that the recession phase should be like that of a natural flood. A large-scale awareness campaign on the risks of prolonged flooding, illustrated by the deterioration of low-lying areas in the irrigated agricultural areas nearby, could be an opportunity to do so.

7. The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

The process of drafting the management plan using a participatory approach allowed the stakeholders to operationally define the appropriate scale. The management plan was adopted for an initial five year period and is currently being reviewed.

8. Recognising the varying temporal scales and lag-effects that characterise ecosystem processes, objectives for ecosystem management should be set for the long term.

Because of the strong flood-related seasonality of Sahelian floodplain and delta ecosystems, many species groups responded very quickly to improved management, especially the fish and annual and perennial grasses which are so important for local livelihoods. Because of the careful and gradual way in which the water was released, however, immediate compensation measures had to be put in place to secure livelihoods during the period leading to full implementation. These measures were also a step towards establishing constructive relationships. Some communities had lost their traditional rangelands when they were absorbed by Diama reservoir, which was managed by OMVS with the sole aim of lowering pumping costs for irrigated agriculture. These excluded stakeholders would therefore not benefit from improved management in other parts of the delta. Measures such as promoting horticulture, hiring labourers for construction work (including the park's field station), recruiting *"guards"* locally, etc. made it possible to address some of the more pressing needs without increasing pressure on the ecosystems being rehabilitated.

The functional and structural revival of the mangrove and floodplain woodland ecosystems obviously required more time. This was also true for breeding colonies of piscivorous birds (especially the tree-nesting species). Some initial restrictions have therefore been placed on techniques used to harvest the *Acacia* seedpods used in leather tanning, and on the taking of juvenile cormorants for human consumption. The need to ensure that the inter-annual variations in the flood release regime are as close as possible to the natural regime has, however, proved to be a difficult concept to introduce. Such variations would need to include (relatively) dry years. This would mean accepting lower productivity rates and foregoing tourist revenue (fewer waterbirds). The tendency to set production targets higher every year may have contributed to the expansion of less desirable vegetation (sedges, reed-mace). On this issue both the local communities and the protected area authority continue to have difficulty in adopting a long-term view.

9. Management must recognise that change is inevitable.

The need for adaptive management was incorporated into both the progressive implementation process and the careful monitoring of the effects of the managed flood releases on local ecology and peoples' livelihoods. As the project's aim was restoration-oriented, change was in fact the desired outcome, but the changes were predictable only in the most general terms (more water, more resources). Once full implementation was achieved and direct donor-supported technical advice was downscaled (while there was still no fully operational local scientific advisory board), however, the initial flexibility and adaptability of the project decreased. The tendency to apply the management plan more strictly was further increased by the rapid turnover of key staff which affected institutional memory. Moreover, as stated under principle 8, the need for an occasional *"drought"* to *"reset the clock"* for herbaceous vegetation was not fully appreciated.

Obtaining approval for a written management plan from a wide range of stakeholders at many hierarchical levels is a complex (and expensive) proposition and can be an obstacle to achieving the required adaptability. After each flood season, local stakeholder feedback sessions should therefore be held in order to assess the need to adjust the flood release calendar.

10. The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

The presidential decree creating the National Park explicitly allowed sustainable resource extraction by local users in certain areas, and gave protected area managers the task of promoting sustainable resource use and livelihood-enhancement in all areas covered by the management plan, regardless of their protected area status.

The park *"guards"* had generally been assigned an advisory and awareness-raising role rather than a strict law enforcement remit. Biodiversity has continued to increase thus far, and conservation efforts can thus be considered successful despite fairly high levels of resource use. Inappropriate use is not unheard of, but quite often the unsustainable practices are reported to the park authority by other resource users or even halted internally.

The current phase of the project, whose goal is to develop a Biosphere Reserve on a participatory basis, endeavours to create a patchwork of areas with variable (and seasonally varying) levels of protection. Such a complex interweaving of conservation and use requires full stakeholder awareness and consent.

11. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.

Substantial time and effort were spent collecting historical information, conducting in-depth interviews with the village elders, doing transect walks with resource users, etc. The partnership with Nouakchott University's Wetlands Research

Picture 33: Field visits with resource users provided much information on stakeholder perception of ecosystem functioning and on their use strategies.

Group – GREZOH (whose membership covers most natural sciences as well as agronomy, geography and socioeconomics), along with input from a large number of local and foreign students on topics identified as knowledge gaps in the management plan (hydrodynamics, groundwater fluctuations, salinity and water quality, botany, fisheries, livestock, reptiles, birds, mammals, economic aspects of resource use, etc.) greatly expanded the information base. Close working contacts between observant locals and dynamic young scientists from various backgrounds and disciplines contributed to the formalisation of local traditional knowledge. Thanks to the perseverance of these researchers in their interviews, a plethora of details about pre-dam ecosystem functioning and resource use was offered up, giving local users a sense of pride and a feeling that they were making a valuable contribution. Some of the research was done in collaboration with resource users, such as assessing the different techniques for harvesting perennial grasses, selecting suitable plots for replanting *Acacia nilotica*, setting up exclosures, replanting mangroves, etc. Participatory research was felt to be an effective tool for facilitating the implementation of management decisions.

12. The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

A good mix of natural and social sciences was sought from the outset. Capacity training in the different fields was provided to park staff, local inhabitants, members of the municipal council and of decentralised administrations. The involvement of a wide range of groups (ethnic, tribal, caste, age, gender) in project activities, monitoring and research was actively pursued. At national level, a major step forward came in the shape of a field visit with all the relevant ministries and technical departments involved in drafting the Integrated Coastal Zone Management Plan. This brought some of the nation's important decision-makers into direct contact with the ecosystem restoration and livelihood enhancement approach of the project.

As part of the communication strategy, project results were presented at a wide range of workshops. The networking activities of the GREZOH, an influential group in the new urban middle class, were instrumental in broadening the constituency to include politicians and economic leaders. Potential champions of wetland management were identified and encouraged. A guided tour of the area, especially targeting the *"hardline opponents"*, *i.e.* key people from the rice-farming lobby, OMVS staff etc. was organised in 1999 and helped to change some perceptions.

8. Lessons learned

The Diawling experience has shown that:

- involving local communities in the management of a protected wetland is both feasible and beneficial (see also Sherbinin & Claridge, 2000) and that the ecosystem approach (Pirot *et al.,* 2000), applied to managed flood releases used to restore the structure and function of a severely damaged wetland ecosystem, can have positive impacts on biodiversity and livelihoods.

Fundamentals of the approach have been:

- an open-minded and respectful attitude, permeated by an appreciation of the local historical and socio-cultural background.
- the idea that development issues are to be taken as seriously as environmental issues.
- since the management plan development process targeted the entire lower delta, emphasis was placed on linkages with, rather than the boundaries of, the protected area.
- continuous presence in the field as a prerequisite, the advantage being that signals from both the ecosystem and the stakeholders can be read and flexible responses provided.

In relationships with the local communities, key concepts were **trust**, **benefits** and the **integration of indigenous knowledge**.

Trust

- in order to build a relationship based on trust, a project must move slowly and carefully. Confidence can only be gained through proving assertions with action, and such results take time. Mistakes are not easily corrected. Similarly, the identification of key actors, possibly absent from the public stage, requires ample time.
- it is important to clearly set out what can be achieved through ecosystem restoration, but also to make clear that some things are unlikely or impossible. This gives stakeholders a fairer idea of what to expect. The rule of thumb here is to predict less than you expect (in public) and to let the stakeholders enjoy telling you the outcome is even better (or worse) than you predicted.
- make no false promises about what the project can do. If approached with expectations that cannot be fulfilled, answer that you will try to interest another development partner in this particular aspect and do so. Only in this way can one be perceived as an *"honest broker"*.

- conflict avoidance may seem attractive, but managed conflict is better than simmering resentment. Within and between the communities, some unresolved natural resource use conflicts and historical inequities may have to be reopened. A certain degree of confrontation may be necessary to explore the limits of project intervention.

Benefits

- local community adhesion to sustainable resource use is proportional to the benefits they will reap from it. Long-term benefits accruing to the communities are the sustained and increased availability of resources, the improved control over marketing channels and some measure of exclusive use rights. Ecosystem rehabilitation takes time, and under economic duress stakeholders' immediate needs have to be addressed

Integration of indigenous knowledge

- local stakeholders have a longstanding relationship with the ecosystem. Although at times their explanations of certain phenomena may seem far-fetched, scientific arrogance should be avoided. Patiently drawing out the experience of observant locals can be highly rewarding.
- local knowledge should be formalised through scientific investigation. The project-facilitated interactions between the two knowledge systems provided considerable stimulus to the development of the management plan. Joint monitoring and participatory research increased awareness and local capacity, scientific results contributed to the consensus flood scenario debate.

For the institution responsible for ecosystem management, several important guidelines should be followed:

- value individual competence, responsibility and creativity while emphasizing that these should find expression through team effort.
- get input from a wide range of disciplines, with an emphasis on the social sciences (sociological issues being the most difficult to tackle).
- build a constituency at national level including decision makers, other institutions, and the scientific community through networking, field visits, workshops, etc.

In relationships with development partners it is important to:

- emphasise the need for the project to be flexible in its responses (this assumes that flexible use of funds is possible). As the local communities responded very rapidly to the new hydraulics, so the project must be able to keep pace with changing perceptions and use the opportunities arising from these changes.

- explain that building the social capital needed to achieve sustainable results through participatory processes takes longer than building infrastructure. Creating a new protected area with a functioning joint management system can be reasonably expected to take a generation.
- design an exit strategy in which responsibility is gradually handed over as local capacity increases.

9. Opportunities

9.1. A managed flood release laboratory

The initial directive for the managed flood releases was *"caution"*. Damage to infrastructure and irreversible ecosystem changes were to be avoided. Ecosystem response monitoring and stakeholder feedback on the pilot releases were used to design the next year's flood in a *"learning by doing"* approach. Still, the consensus flood scenario may not be ideal for biodiversity conservation in the long term, and some measure of inter-annual variability may have to be introduced. Also, the artificial system could potentially outperform the natural system, but extrapolating ecosystem response beyond the observed range of floods is risky. Such *"experiments"* should preferably be based on scientific knowledge and conducted in a modelled environment first.

The lower delta offers a perfect setting for scientific investigations into the responses of various plant and animal communities to variations in flood extent and duration. Research could greatly contribute to our understanding of the underlying relationships and provide insights into the functioning of floodplain and estuarine ecosystems, thus generating knowledge which is difficult to obtain through observing natural systems. These ecosystem responses can then be modelled and used to explore untested scenarios, some of which may increase stakeholder benefits, biodiversity values and attractiveness for tourists.

9.2. A transboundary Biosphere Reserve

The management plan was specifically written for the entire lower delta, of which Diawling National Park makes up a relatively small part. Development activities were initiated with all interested communities, even those living some distance from the park.

The impact of the rehabilitation project on natural resources was initially strongest in the parts of the delta where the park had control over the water supply, first the Bell basin and later the Diawling basin. In the Ntiallakh basin the flood releases, sustained by the park's dry season floods, led to colonisation by young *Avicennia germinans* in areas littered with dead mangrove trees (Picture 10). The areas to the north of the park were also influenced by the rehabilitation effort. The Tumbos marshes and Chat Tboul were incorporated into Mauritania's third Ramsar site in 2000, and even the southern depressions of the Aftout es Saheli were flooded and attracted large numbers of waterbirds (Measson, 2001).

With increased awareness among the population about the development potential of the restored wetlands, the time was ripe for the establishment of a Biosphere

Reserve, preferably encompassing both banks of the river. The current (2001-2004) phase of the project has initiated this process, which will require the support of more stakeholders with a wider range of interests.

9.3. An environmental code of conduct on water management for OMVS

To counter the upstream-downstream hydraulic inequity, the park and the project did their utmost to influence the management policy of Diama reservoir. Over 3,000 ha of the park, the areas formerly used for fishing and gathering by the inhabitants of Birette, lie within the impoundment and have become a waterborne disease-ridden *Typha domingensis* monoculture (Pictures 11 and 12). Lowering the water level in the reservoir during the dry season, or occasionally even letting in sea water, could be highly beneficial.

There is a need to revise the operational guidelines for the management of the reservoir to include ecological criteria such as downstream salinity, minimum flood height and maximum slope of the ascending arm of the flood releases. For example, the water level in the floodplain should not increase by more than 1 cm per day to allow the *Sporobolus robustus* stands in the Ntiallakh to develop (Duvail *et al.,* 2002b). Improved dam operation could be highly beneficial for the natural resource base available to the coastal dune communities, for example by recharging their scarce groundwater reserves.

Bibliography

Adams A., 1977. Le long voyage des gens du Fleuve. Maspéro, Paris, France, 222 p.

Adams A., 1999. Social impacts of an African dam: equity and distributional issues in the Senegal River Valley. Report for the World Commission on Dams (WCD), 35 p. + annexes.

Baillargeat, P., 1964. Hydrologie du delta du Sénégal (rive droite du fleuve). SOGREAH, Campagnes 1961, 1962 et 1963. Extrait du R 8 622, 84 p. + annexes.

Barry, B., 1985. Le royaume du Waalo : Le Sénégal avant la conquête. Maspéro, Paris, France, 393 p.

Barusseau, J.P., Ba, M., Descamps, C., Salif Diop, E., Diouf, B., Kane, A., Saos, J.L., Soumare, A., 1998. Morphological and sedimentological changes in the Senegal River estuary after the construction of the Diama Dam. Journal of African Earth Sciences, Vol. 26, n°2, pp. 317 - 326.

BDPA-SCETAGRI, 1993. Schéma d'aménagement de l'espace rural dans le delta du fleuve Sénégal. Ministère du Développement Rural et de l'Environnement, Nouakchott, Mauritania, 63p. + annexes.

Bousso, T., 1997. The estuary of the Senegal River: the impact of environmental changes and the Diama dam on resource status and fishery conditions. In Remane, K. (Ed.) *"African inland fisheries, aquaculture and the environment"*, Fishing News Books, Oxford, U.K., pp. 45-65.

Colas, F. (Ed.), 1997. Environnement et littoral mauritanien. Actes du colloque, 12-13 juin 1995, Nouakchott, Mauritanie. CIRAD, Montpellier, France.

Duvail, S., 2001. Scénarios hydrologiques et modèles de développement en aval d'un grand barrage. Les usages de l'eau et le partage des ressources dans le delta mauritanien du fleuve Sénégal. Unpublished Ph.D. Thesis, Louis Pasteur University, Strasbourg, France, 313 p.

Duvail, S. & Hamerlynck, O., 2003. Hydraulic modelling as a tool for the joint management of a restored wetland: sharing the benefits of managed flood releases from the Diama dam reservoir. Hydrology and Earth System Sciences, Vol.7, n°1, pp. 133-146.

Duvail, S., Bergkamp, G., Baba, M.L. ould, Acreman, M., Hamerlynck, O., 2002a. Modélisation hydraulique et gestion sociale de l'eau. *In* Orange, D. *et al.* (Eds.). *"Gestion Intégrée des Ressources Naturelles dans les Zones Inondables Tropicales"*. IRD Editions, Paris, France, pp.815-834.

Duvail S., Hamerlynck O., Baba M.L. ould, 2002b. Une alternative à la gestion des eaux du fleuve Sénégal ? *In* Bergkamp G., Pirot J. Y., & Hostettler S. (Eds.).*"Integrated Wetlands and Water Resources Management"*: Proceedings of a workshop held at the 2nd International Conference on Wetlands and Development, Wetlands International, IUCN, WWF, Gland, Switzerland, pp. 89-97.

Gannett Fleming Corddry & Carpenter Inc. and ORGATEC, 1980. Assessment of Environmental Effects of proposed developments in the Senegal River Basin. Organisation pour la Mise en Valeur du fleuve Sénégal, Dakar, Senegal, 158 p.

GERSAR-SCP & SONADER, 1987. Schéma Directeur d'Aménagement du delta Mauritanien du fleuve Sénégal. Ministère du Développement Rural et de l'Environnement, Nouakchott, Mauritania.

Hamerlynck, O., 1997. Plan Directeur d'Aménagement du Parc National du Diawling et de sa zone périphérique, 1997-2000. Ministère du Développement Rural et de l'Environnement, Nouakchott, Mauritania, 65 p. + annexes.

Hamerlynck, O. & Cazottes, F., 1998. Le Parc National du Diawling : infrastructures hydrauliques pour la restauration d'une plaine d'inondation et la création d'un estuaire artificiel. Sud Sciences et Technologies, EIER, Ouagadougou, Vol. 1, pp. 28-38.

Hamerlynck, O. & Messaoud, B. ould, 2000. Suspected breeding of Lesser Flamingo *Phoeniconaias minor* in Mauritania. African Bird Club Bulletin, Vol. 7, n°2, pp. 109-110.

Hamerlynck, O., Baba, M.L. ould, Duvail, S., 1999. The Diawling National Park, Mauritania: joint management for the rehabilitation of a degraded coastal wetland. Vida Silvestre Neotropical, Vol 7, n°1, pp. 59-70.

Hamerlynck, O., Messaoud, B. ould, Braund, R., Diagana, C.H., Diawara, Y., Ngantou, D., 2002. Crues artificielles et cogestion: la réhabilitation des plaines inondables au Sahel. Le Waza Logone (Cameroun) et le bas-delta du fleuve Sénégal (Mauritanie). *In* Orange, D. *et al.* (Eds.). *"Gestion Intégrée des Ressources Naturelles dans les Zones Inondables Tropicales"*. IRD Editions, Paris, France, pp. 475-500.

Hollis, G.E., 1996. Hydrological inputs to management policy for the Senegal River and its floodplain. *In* Acreman M.C. and Hollis G.E., *"Water management and Wetlands in Sub-Saharan Africa"*, IUCN, Gland, Switzerland & Cambridge, U.K., pp. 155-184.

JICA, MDRE, SONADER, 1997. Etude de faisabilité du projet de développement du système d'irrigation agricole dans le haut delta du fleuve Sénégal. Nippon Koei Co. Ltd, Taiko consultants Co. LTD, Aero Asahi Corporation, 2 tomes, Tome 1 : 113 p., Tome 2 : annexes.

Laë, R., 1997. Effects of climatic changes and developments on continental fishing in West Africa : the examples of the central delta of the Niger in Mali and coastal lagoons in Togo. *In*: *African inland Fisheries, Aquaculture and the Environment,* K. Remane, (Ed.), Fishing News Books, Oxford, UK.66–86.

Lecocq, G., 1987. Germination et croissance du bourgou *(Echinochloa stagnina).* Faculté des sciences Agronomiques, Gembloux, Belgium, 79 pp.

Méasson, L., 2001. La Réserve Naturelle du Chat Tboul : zone humide internationale ? Mémoire de DU Ingénierie de l'Espace Rural, Université de Lyon III et Savoie, 96 pp.

Michel, P., 1973. Les bassins du fleuve Sénégal et Gambie: étude géomorphologique. Thèse de Géographie, Université de Strasbourg, Mémoire ORSTOM No 63, Paris, France, 753 p.

Mulato, C., 1994. Elevage en Mauritanie : Quelles perspectives ? Projet Trarza, Ministère du Développement Rural et de l'Environnement, Nouakchott, Mauritania, 17 p.

Naurois, R. de, 1969. Peuplement et cycle de reproduction des oiseaux de la côte occidentale d'Afrique. Mémoires du Musée d'Histoire Naturelle série A. Zoologie, 57, 312 p.

OMVS - SOGREAH - Coyne & Bellier, 1998. Etude complémentaire des endiguements du fleuve Sénégal. Première phase. Rapport d'inventaire – diagnostic. OMVS, Dakar, Senegal, 64 p. + annexes 12 p.

Pirot, J.Y., Meynell, P.J. Elder, D., 2000. Ecosystem Management: Lessons from around the World. A Guide for Development and Conservation Practioners. IUCN, Gland, Switzerland and Cambridge UK, 129 p.

Salem-Murdock, M., Niasse, M., Magistro, J., Nutall, C. Kane, O., Grimm, K., &Sella, K., 1994. Les barrages de la controverse. Le cas du fleuve Sénégal, Harmattan, Paris, France, 318 p.

Schmitz, J., 1990. Le fleuve Sénégal : ligne de front ou voie de passage, Afrique Contemporaine 154, pp. 70-74.

Sherbinin, A. de & Claridge, G., 2000. Involving local communities and indigenous people in wetland management - a resource paper. Ramsar handbooks for the wise use of wetlands. Handbook 5. Establishing and strengthening local communities' and indigenous people's participation in the management of wetlands. Ramsar convention bureau, Gland, Switzerland, pp. 21-52.

Taylor, V. (Ed.), 1994. African waterfowl census 1993. Les dénombrements internationaux d'oiseaux d'eau en Afrique, 1993. Wetlands International, Slimbridge, U.K. 156 pp.

Van der Zon, A., 1992. Graminées du Cameroun. Wageningen Agr. Univ. Papers, 92, I: 558 p.

Verhoef, H., 1996. Health aspects of Sahelian floodplain development. In Acreman M.C. and Hollis G.E., "Water management and Wetlands in Sub-Saharan Africa", IUCN, Gland, Switzerland & Cambridge, U.K., pp. 35 -50.

Vernet, R., 1993. Préhistoire de la Mauritanie. Centre Culturel Français de Nouakchott, Sépia, Nouakchott, Mauritania, 427 p.

Vernet, R., 1997. Rapport de mission au Parc National du Diawling. Centre Régional Inter-Africain d'Archéologie, Nouakchott, Mauritania, 2 p.

Appendices

Appendix 1: Principles of the ecosystem approach (Convention on Biological Diversity)

Recommendation V/10 adopted by SBSTTA

Ecosystem approach: further conceptual elaboration

The Subsidiary Body on Scientific, Technical and Technological Advice recommends that the Conference of the Parties at its fifth meeting:

Calls upon Parties, other Governments, and international organizations to apply the ecosystem approach, in line with the principles and guidance contained in the annex to the present recommendation, in particular in the context of activities developed within the thematic areas of the Convention, and national policies and legislation;

Endorses these principles and guidance, as reflecting the present level of common understanding and encourages further conceptual elaboration;

Invites Parties, other Governments and relevant bodies to identify case-studies and implement pilot projects, and to organize, as appropriate, regional, national and local workshops, and consultations aiming to enhance awareness, share experiences, including through the clearing-house mechanism, and strengthen regional, national and local capacities on the ecosystem approach;

Requests the Executive Secretary to prepare a synthesis of case-studies and lessons learned;

Requests the Subsidiary Body on Scientific, Technical and Technological Advice to prepare guidelines for the implementation of the ecosystem approach, on the basis of case-studies and lessons learned, and to review the incorporation of the ecosystem approach into various programmes of work of the Convention; and

Addresses the need for support for capacity-building to implement the ecosystem approach.

A. Description of the ecosystem approach

The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Thus, the application of the ecosystem approach will help to reach a balance of the three objectives of the Convention: conservation; sustainable use; and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources.

An ecosystem approach is based on the application of appropriate scientific methodologies focused on levels of biological organization, which encompass the essential structure, processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems.

This focus on structure, processes, functions and interactions is consistent with the definition of "ecosystem" provided in Article 2 of the Convention on Biological Diversity:

"'Ecosystem' means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit." This definition does not specify any particular spatial unit or scale, in contrast to the Convention definition of *"habitat"*. Thus, the term *"ecosystem"* does not, necessarily, correspond to the terms *"biome"* or *"ecological zone"*, but can refer to any functioning unit at any scale. Indeed, the scale of analysis and action should be determined by the problem being addressed. It could, for example, be a grain of soil, a pond, a forest, a biome or the entire biosphere.

The ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. Ecosystem processes are often non-linear, and the outcome of such processes often shows time-lags. The result is discontinuities, leading to surprise and uncertainty. Management must be adaptive in order to be able to respond to such uncertainties and contain elements of *"learning-by-doing"* or research feedback. Measures may need to be taken even when some cause-and-effect relationships are not yet fully established scientifically.

The ecosystem approach does not preclude other management and conservation approaches, such as biosphere reserves, protected areas, and single-species conservation programmes, as well as other approaches carried out under existing national policy and legislative frameworks, but could, rather, integrate all these approaches and other methodologies to deal with complex situations. There is no single way to implement the ecosystem approach, as it depends on local, provincial, national, regional or global conditions. Indeed, there are many ways in which ecosystem approaches may be used as the framework for delivering the objectives of the Convention in practice.

B. Principles of the ecosystem approach

The following 12 principles are complementary and interlinked, and need to be applied as a whole.

Principle 1: The objectives of management of land, water and living resources are a matter of societal choice.

Rationale: Different sectors of society view ecosystems in terms of their own economic, cultural and societal needs. Indigenous peoples and other local communities living on the land are important stakeholders and their rights and interests should be recognized. Both cultural and biological diversity are central components of the ecosystem approach, and management should take this into account. Societal choices should be expressed as clearly as possible. Ecosystems should be managed for their intrinsic values and for the tangible or intangible benefits for humans, in a fair and equitable way.

Principle 2: Management should be decentralized to the lowest appropriate level.

Rationale: Decentralized systems may lead to greater efficiency, effectiveness and equity. Management should involve all stakeholders and balance local interests with the wider public interest. The closer management is to the ecosystem, the greater the responsibility, ownership, accountability, participation, and use of local knowledge.

Principle 3: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

Rationale: Management interventions in ecosystems often have unknown or unpredictable effects on other ecosystems; therefore, possible impacts need careful consideration and analysis. This may require new arrangements or ways of organization for institutions involved in decision-making to make, if necessary, appropriate compromises.

Principle 4: Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:
(a) Reduce those market distortions that adversely affect biological diversity;
(b) Align incentives to promote biodiversity conservation and sustainable use;
(c) Internalize costs and benefits in the given ecosystem to the extent feasible.

Rationale: The greatest threat to biological diversity lies in its replacement by alternative systems of land use. This often arises through market distortions, which undervalue natural systems and populations and provide perverse incentives and subsidies to favour the conversion of land to less diverse systems.

Often those who benefit from conservation do not pay the costs associated with conservation and, similarly, those who generate environmental costs (e.g. pollution) escape responsibility. Alignment of incentives allows those who control the resource to benefit and ensures that those who generate environmental costs will pay.

Principle 5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

Rationale: Ecosystem functioning and resilience depends on a dynamic relationship within species, among species and between species and their abiotic environment, as well as the physical and chemical interactions within the environment. The conservation and, where appropriate, restoration of these interactions and processes is of greater significance for the long-term maintenance of biological diversity than simply protection of species.

Principle 6: Ecosystems must be managed within the limits of their functioning.

Rationale: In considering the likelihood or ease of attaining the management objectives, attention should be given to the environmental conditions that limit natural productivity, ecosystem structure, functioning and diversity. The limits to ecosystem functioning may be affected to different degrees by temporary, unpredictable or artificially maintained conditions and, accordingly, management should be appropriately cautious.

Principle 7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

Rationale: The approach should be bounded by spatial and temporal scales that are appropriate to the objectives. Boundaries for management will be defined operationally by users, managers, scientists and indigenous and local peoples.

Connectivity between areas should be promoted where necessary. The ecosystem approach is based upon the hierarchical nature of biological diversity characterized by the interaction and integration of genes, species and ecosystems.

Principle 8: Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.

Rationale: Ecosystem processes are characterized by varying temporal scales and lag-effects. This inherently conflicts with the tendency of humans to favour short-term gains and immediate benefits over future ones.

Principle 9: Management must recognize the change is inevitable.

Rationale: Ecosystems change, including species composition and population abundance. Hence, management should adapt to the changes. Apart from their inherent dynamics of change, ecosystems are beset by a complex of uncertainties and potential *"surprises"* in the human, biological and environmental realms. Traditional disturbance regimes may be important for ecosystem structure and functioning, and may need to be maintained or restored. The ecosystem approach must utilize adaptive management in order to anticipate and cater for such changes and events and should be cautious in making any decision that may foreclose options, but, at the same time, consider mitigating actions to cope with long-term changes such as climate change.

Principle 10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

Rationale: Biological diversity is critical both for its intrinsic value and because of the key role it plays in providing the ecosystem and other services upon which we all ultimately depend. There has been a tendency in the past to manage components of biological diversity either as protected or non-protected. There is a need for a shift to more flexible situations, where conservation and use are seen in context and the full range of measures is applied in a continuum from strictly protected to human-made ecosystems.

Principle 11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.

Rationale: Information from all sources is critical to arriving at effective ecosystem management strategies. A much better knowledge of ecosystem functions and the impact of human use is desirable. All relevant information from any concerned area should be shared with all stakeholders and actors, taking into account, inter alia, any decision to be taken under Article 8(j) of the Convention on Biological Diversity. Assumptions behind proposed management decisions should be made explicit and checked against available knowledge and views of stakeholders.

Principle 12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Rationale: Most problems of biological-diversity management are complex, with many interactions, side-effects and implications, and therefore should involve the necessary expertise and stakeholders at the local, national, regional and international level, as appropriate.

C. Operational guidance for application of the ecosystem approach

In applying the 12 principles of the ecosystem approach, the following five points are proposed as operational guidance.

1. Focus on the functional relationships and processes within ecosystems

The many components of biodiversity control the stores and flows of energy, water and nutrients within ecosystems, and provide resistance to major perturbations. A much better knowledge of ecosystem functions and structure, and the roles of the components of biological diversity in ecosystems, is required, especially to understand: (i) ecosystem resilience and the effects of biodiversity loss (species and genetic levels) and habitat fragmentation; and (ii) determinants of local biological diversity in management decisions. Functional biodiversity in ecosystems provides many goods and services of economic and social importance. While there is a need to accelerate efforts to gain new knowledge about functional biodiversity, ecosystem management has to be carried out even in the absence of such knowledge. The ecosystem approach can facilitate practical management by ecosystem managers (whether local communities or national policy makers).

2. Promote the fair and equitable access to the benefits derived from the functions of biological diversity in ecosystems and from the use of its components

Benefits that flow from the array of functions provided by biological diversity at the ecosystem level provide the basis of human environmental security and sustainability. The ecosystem approach seeks that the benefits derived from these functions are distributed equitably. In particular, these functions should benefit the stakeholders responsible for their production and management. This requires, inter alia: capacity-building, especially at the level of local communities managing biological diversity in ecosystems; the proper valuation of ecosystem goods and services; the removal of perverse incentives that devalue ecosystem goods and services; and, consistent with the provisions of the Convention on Biological Diversity, where appropriate, their replacement with local incentives for good management practices.

3. Use adaptive management practices

Ecosystem processes and functions are complex and variable. Their level of uncertainty is increased by the interaction with social constructs, which need to be better understood. Therefore, ecosystem management must involve a learning process, which helps to adapt methodologies and practices to the ways in which these systems are being managed and monitored. Implementation programmes should be designed to adjust to the unexpected, rather than to act on the basis of a belief in certainties. Ecosystem management needs to recognize the diversity of social and cultural factors affecting natural-resource use. Similarly, there is a need for flexibility in policy-making and implementation. Long-term, inflexible decisions are likely to be inadequate or even destructive. Ecosystem management should be envisaged as a long-term experiment that builds on its results as it progresses. This *"learning-by-doing"* will also serve as an important source of information to gain knowledge of how best to monitor the results of management and evaluate whether established goals are being attained. In this respect, it would be desirable to establish or strengthen capacities of Parties for monitoring.

4. Carry out management actions at the scale appropriate for the issue being addressed, with decentralization to lowest level, as appropriate

As noted in section A above, an ecosystem is a functioning unit that can operate at any scale, depending upon the problem or issue being addressed. This understanding should define the appropriate level for management decisions and actions. Often, this approach will imply decentralization to the level of local communities. Effective decentralization requires proper empowerment, which implies that the stakeholder both has the opportunity to assume responsibility and the capacity to carry out the appropriate action, and needs to be supported by enabling policy and legislative frameworks. Where common property resources are involved, the most appropriate scale for management decisions and actions would necessarily be large enough to encompass the effects of practices by all the relevant stakeholders. Appropriate institutions would be required for such decision-making and, where necessary, for conflict resolution. Some problems and issues may require action at still higher levels, through, for example, transboundary cooperation, or even cooperation at global levels.

5. Ensure intersectoral cooperation

As the primary framework of action to be taken under the Convention, the ecosystem approach should be fully taken into account in developing and reviewing national biodiversity strategies and action plans. There is also a need to integrate the ecosystem approach into agriculture, fisheries, forestry and other production systems that have an effect on biodiversity. Management of natural resources, according to the ecosystem approach, calls for increased intersectoral communication and cooperation at a range of levels (government ministries, management agencies, etc.). This might be promoted through, for example, the formation of inter-ministerial bodies within the Government or the creation of networks for sharing information and experience.

D. Other remarks

The ecosystem approach should be applied in each of the thematic and cross-cutting work programmes of the Convention, based upon the 12 principles and using the five points of operational guidance derived therefrom.

The application of the ecosystem approach can help to promote delivery to people of the full array of benefits derived from the functions of biological diversity at the ecosystem level. Lessons learned from case-studies on the ecosystem approach that take into account the three objectives of the Convention should be widely promoted.

Appendix 2: Chronology of the implementation of the management plan for Diawling National Park

1970s	First plans for a protected area in the Mauritanian lower delta.
1980	Environmental impact assessment of Diama dam proposes a protected area and an artificial estuary.
1984	Diawling National Park listed as a priority in the National Action Plan for the Environment.
1985	Diama dam completed.
1989	IUCN facilitates consultations with administrations and local communities on management options for lower delta.
1990	Strong spring tides cause mass die-off of mangroves and perennial grasses.
1991	Establishment of Diawling National Park by presidential decree, Diama embankment completed.
1994	Multidisciplinary mission, Lemer sluice-gate operational, major water release from Diama contributes to flooding of park basins, Diawling National Park becomes Ramsar site.
1995	Infrastructure work on Ziré and Lekser embankments begins, large flood release from Diama.
1996	Bell basin inflow and outflow operational, first draft management plan completed.
1997	First dry season flood release test.
1998	First test of Cheyal sluice-gate.
1999	Cheyal sluice-gate fully operational.
2000	Chat Tboul becomes Ramsar site.
2001	Studies for future Biosphere Reserve initiated.

Photographs

Olivier Hamerlynck: Pictures 1, 2, 4, 5, 7, 9, 10, 11, 13, 14, 16, 18, 20, 24, 26, 27, 30, 31.
Stéphanie Duvail: Cover photograph, Pictures 3, 6, 12, 13, 14, 15, 17, 19, 21, 22, 23, 25, 29, 32, 33.
Ger Bergkamp: Picture 28.
Ba Amadou: Picture 8.